SCIENCE

AERO/SPACE ENGINEERING

REVIEW OF CURRENT AND FUTURE TRENDS IN AIRCRAFT • MISSILES • ROCKETS • SATELLITES • SPACECRAFT

A New Look for the IAS Staff

Editorial and illustrated organizational chart . . . p. 17

GREEN SHEET: *Late details on ICAS Meeting . . . p. 9*

JUNE / 1960

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AERO/SPACE ENGINEERING

VOLUME 19 / NUMBER 6 June 1960

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LETTERS to the Editor

"Serious Fallacies" Noted in Reliability Presentation

■ The December, 1959, issue carries an article by N. A. Benson entitled "Aircraft Weapon System Reliability." This article presents a novel and rational solution to the problem of establishing a maximum allowable failure rate, and Benson is to be congratulated on so useful an approach. Nevertheless, some serious fallacies are apparent in the presentation, particularly in the engineering decisions based on the allowable failure rate.

For example, the author computes a hypothetical allowable average failure rate of 1/1.2 failures per system flying hour. Since his system contains many different kinds of components, each with its particular failure pattern, it is not unreasonable to suppose that the failure rate of the system as a whole will be approximately constant. Under these circumstances, restricting combat missions to 1.2 hours is of no help—failures will occur as readily in the first 10 min. of flight as in the second or third hour. Indeed, the reliability of the system for one-hour missions will only be 43.5 per cent, using the author's definition of reliability! On the other hand, if all of these failures are centered in one or two short-lived components, we move into the realm of scheduled inspection and preventive maintenance, and must change the values assigned to t_{pi} (periodic inspection) and to M (which covers only unscheduled maintenance).

Second, the author postulates that the parts of the aircraft not subject to such "unscheduled" failures must have a life of at least 300 flying hours without failure. Yet later he states that it may be difficult to attain the required 300-hour mean life. Crudely speaking, a 300-hour mean life implies that half of his components will have failed in 300 hours! Obviously the mean life must be far greater than 300 hours if no failures can be tolerated in the first 300 hours.

Finally, long life on some components will never compensate (in reliability terms) for short life in others. The reliability of each component for a typical one-hour mission is a direct function of its mean life and the scatter about its mean. The reliability of the total system is the product of all the independent component reliabilities, and as such can never be greater than the lowest of the component reliabilities since each factor of the product is less than one.

The general approach for establishing system requirements is most interesting, but some of the conclusions appear extremely dangerous!

R. V. Garvin
Large Jet Engine Dept.
General Electric Company

The Editors welcome letters from readers, although none can be acknowledged. All must be signed, but identities will be withheld on request.

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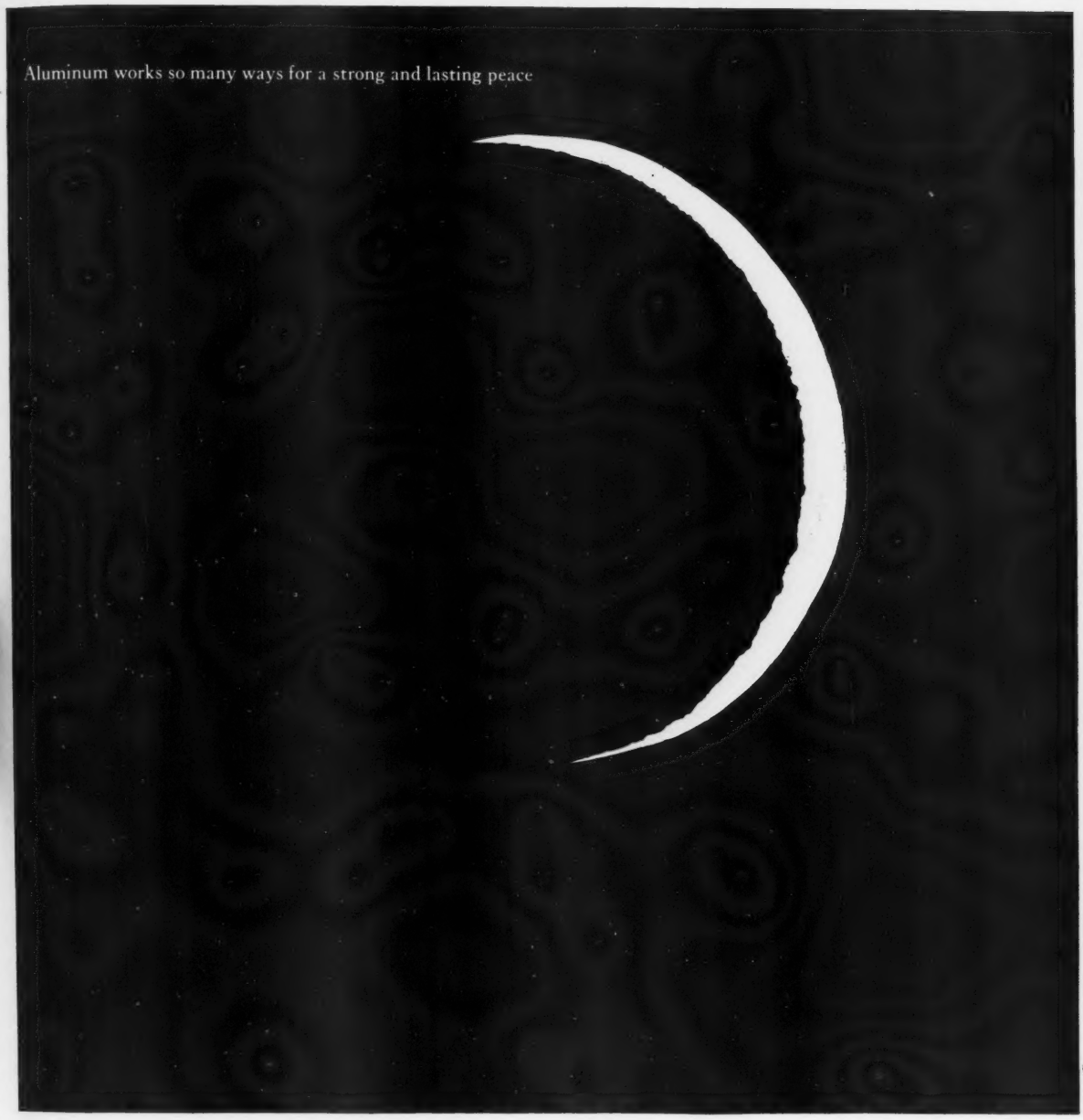

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the Green Sheet

IAS BULLETINS AND LATE NEWS...

June 1960

A THIRD SESSION, CLASSIFIED CONFIDENTIAL, HAS BEEN ADDED TO THE IAS NATIONAL SUMMER MEETING Program for the afternoon of June 30. It will be "Polaris Development Report—1960" and open with a 15-minute orientation sound film. Two members of Lockheed's Missiles and Space Division will present talks—A. L. Lowell, Assistant Development Manager, on "Major Tests and Results", and N. R. Bergrun, Manager of Test Systems Analysis, on "Organization of Polaris Missile Test Analysis Effort." Captain Levering Smith, USN, Technical Division Director of the Navy's Special Projects Office in Washington, will be Chairman. Ken Miles of The Marquardt Corp. is Coordinator.

1960 WINNER OF THE INSTITUTE'S OCTAVE CHANUTE AWARD IS JOSEPH J. TYMCZYSZYN, FAA Flight Test Engineer and Pilot. Presentation will be made at the IAS National Summer Meeting later this month.

THE TWA JETSTREAM CONSTELLATION CHARTERED FOR DELEGATES ATTENDING THE 2ND ICAS CONGRESS in Zurich was filled shortly after announcement of its availability was made. A second plane is unavailable.

COPIES OF PAPERS PRESENTED DURING THE 1960 NUCLEAR CONGRESS are available at 50¢ per copy, or $20 for the complete set of 49 papers, from: The Nuclear Congress, 29 West 39th Street, New York 18, New York. The IAS was one of the 28 participating sponsors supporting the Congress.

EDITOR'S NOTEBOOK: A/SE NEXT MONTH BEGINS THE SECOND SERIES OF TECHNICAL ARTICLES SCHEDULED FOR 1960. Aerospace Engineers will want to watch for all three taking up Support Systems. Those aware that support systems are demanding an increasing slice of weapon system budgets, but who don't have a speaking acquaintance with GOE, GSE, and GSME, will find the first article required reading. Entitled "Scope and Techniques", it has been authored by Beal M. Teague, AFIAS, Principal Engineer, Base Systems Dept., at Martin-Denver, and former IAS Rocky Mountain Section Chairman. A/SE wishes to acknowledge Mr. Teague's help in making this state-of-the-art roundup possible.—A.B.

Requests have been received at IAS National Headquarters for more frequent publication of the identities and professional affiliations of officers of the Institute in a form making ready reference quick and simple. Here's the information:

President:
Lt. Gen. Donald L. Putt, USAF (Ret.), FIAS
President, United Technology Corp.
Sunnyvale, California

V-P, Western Region:
Harold T. Luskin, FIAS
Staff Assistant to Manager
Satellite Systems, Missiles & Space Div.
Lockheed Aircraft Corp.
Sunnyvale, California

Treasurer:
Victor E. Carbonara, FIAS
Consultant
Kollsman Instrument Corp.
Elmhurst, L.I., New York

V-P, Central Region:
Col. Paul H. Dane, USAF, AFIAS
Professor of Thermodynamics
USAF Academy
Lowry AFB, Colorado

V-P, Eastern Region:
Charles Tilgner, Jr., FIAS
Chief Aeronautical Engineer
Grumman Aircraft Engineering Corp.
Bethpage, L.I., New York

IAS Staff Officers:
All at 2 E. 64th St., N.Y. 21, N.Y.
Director: S. Paul Johnston
Secretary: Robert R. Dexter
Controller: Joseph J. Maitan

INTERNATIONAL COUNCIL OF THE AERONAUTICAL SCIENCES

Second International Congress

Zurich, Switzerland 12–16 September 1960

The technical sessions will be held in the Grosser Horsaal für Experimentalphysik of the Eidgenössische Technische Hochschule (ETH), Gloriastrasse 35, Zürich 6. Dr. Theodore von Kármán, President of ICAS, will preside. The program and arrangements for the Congress have been organized by committees chairmanned by M. Maurice Roy, Director of Office National d'Etudes et de Recherches Aéronautiques (ONERA), Paris, France, and Dr. Manfred Rauscher, Professor, ETH. The Registration Desk will be open on Monday, 12 September at 0830 hours.

PROGRAM

Monday, 12 September

1000 Hours — New Physics Hall

Opening Session

Daniel and Florence Guggenheim Memorial Lecture

The Role of Entropy in the Aerospace Sciences—Jakob Ackeret, Prof., Institut für Aerodynamik, Eidgenössische Technische Hochschule, Switzerland.

1400 Hours — New Physics Hall

Hypersonic Flow

Possibilités et Limites Actuelles de la Théorie des Ecoulements Hypersoniques—Jean Pierre Guiraud, Ingenieur de Recherches, ONERA, France.

A Paper to be Presented by the Academy of Sciences, USSR.

The Uses of Shock Tubes for Research on Hypersonic Flow—D. W. Holder, Dep. Ch. Scien. Officer, and D. L. Schultz, Prin. Scien. Officer, Natl. Physical Lab., UK.

A Paper to be Presented by the Academy of Sciences, USSR.

1400 Hours — Small Physics Hall

Boundary Layer Flow

Beiträge zur Theorie der dreidimensionalen Grenzschichten—J.A. Zaat, Nationaal Luchtvaartlaboratorium, Holland.

Instability of Laminar Boundary Layers—J. T. Stuart, Prin. Scien. Officer, Aerodyn. Div., Natl. Physical Lab., UK.

Some Aspects of Boundary Layer Transition at Subsonic Speeds—Itiro Tani, Prof., Aeronautical Res. Inst., Univ. of Tokyo, Japan.

Boundary Layer Transition at the Leading Edge of Thin Wings and its Effect on General Nose Separation—R. A. Wallis, Sr. Scien. Officer, Australian Def. Scien. Svce., Aeronautical Res. Labs., Dept. of Supply, Australia.

Boundary Layer Separation at High Speeds—A. Naumann, Prof., Deutsche Versuchsanstalt für Luftfahrt, Germany.

Tuesday, 13 September

0830 Hours — New Physics Hall

Boundary Layer, Transonic and Supersonic Flow

Aircraft Shapes and Their Aerodynamics for Flight at Supersonic Speeds—Dietrich Küchemann, Head, Supersonics Div., Royal Aircraft Estab., UK.

Aerodynamic Design of Swept Wings and Bodies for Transonic Speeds—R. C. Lock and E. W. E. Rogers, Prin. Scien. Officers, Aerodyn. Div., Natl. Physical Lab., UK.

The Design of Wing Sections for Swept Wings at Transonic and Supersonic Speeds—H. H. Pearcey, Sr. Prin. Scien. Officer, Aerodyn. Div., Natl. Physical Lab., UK.

A Paper to be Presented by the Academy of Sciences, USSR.

0830 Hours — Small Physics Hall

Fatigue of Materials

Stress Corrosion Cracking of High Strength Steel—or Hydrogen Embrittlement—Ivar Weibull, Head of Materials Lab., Saab Aircraft Co., Sweden.

Etude Microscopique de la Fissuration par Fatigue a Haute Fréquence—François Girard, Ingénieur de Recherches, ONERA, France.

The Notched Fatigue Properties of High Tensile Steels—W. A. Morgan, Hd., and R. K. Buhr, Sr. Scien. Officer, Ferrous Metals Sect., Phys. Metallurgy Div., Dept. of Mines and Tech. Surveys, Canada.

Some Aspects of Fatigue in Aircraft Structures—J. Schijve, Structs. and Mtls. Dept., Natl. Aeronautical Res. Inst., Holland.

1400 Hours — New Physics Hall

Supersonic Flow

A Paper to be Presented by the Academy of Sciences, USSR.

Theoretical and Experimental Studies of Cambered and Twisted Wings Optimized for Flight at Supersonic Speeds—C. E. Brown, Ch., Theoretical Mech. Div., E. B. Klunker, and F. E. McLean, Aeronautical Res. Engrs., Langley Res. Center, NASA, USA.

Some Experimental Results of Generating High Frequency Oscillating Shock-Waves and Oscillating Shock-Wave Boundary Layer Interaction at Supersonic Speeds—Wladyslaw Fiszdon, Prof. of Aeronautics, Tech. Univ. Warsaw, Poland.

A Paper to be Presented by the Academy of Sciences, USSR.

1400 Hours — Small Physics Hall

Aerothermochemistry

Some Contributions to Laminar Flame Theory—Gregorio Millan, Advisor, and Ignacio da Riva, Aeronautical Engr., Instituto Nacional de Técnica Aeronáutica (INTA) Spain.

Etude de la Combustion dans les Fusées à Lithergol—André Moutet, Chef de Groupe, and Marcel Barrère, Chef de Division, ONERA, France.

Effect of a Shock-Wave in a Burning Solid Propellant—Ellis M. Landsbaum, Res. Group Supvsr., Solid Propellant Rockets Sect., Jet Prop. Lab., CIT, USA.

Elucidation of Combustion Instability in Solid Propellant Rockets—Seiichiro Kumagai, Prof., Dept. of Aeronautics, Faculty of Engrg., Univ. of Tokyo, Japan.

A Paper to be Presented by the Academy of Sciences, USSR.

Wednesday, 14 September

0830 Hours — New Physics Hall

Non-Stationary Transonic Flow

Non-Stationary Transonic Flow Past Airfoil and Revolution

Bodies at a Zero Angle of Attack—Carlo Ferrari, Prof., Politecnico, Centro Dinamica dei Fluidi, Italy.
A Paper to be Presented by the Academy of Sciences, USSR.

0830 Hours — Small Physics Hall

Air Transport

Operations Research in the Basic Design of YS-11 Transport Airplane—Hidemasa Kimura, Prof. of Aeronautical Engrg., Faculty of Engrg., Nihon Univ.; Jiro Kondo, Prof., Tokyo Univ.; and Shizuo Kikuhara, Tech. Advisor, Shin-Meiwa Indus. Co., Ltd., Japan.
Airline Economy in the Turbine Era—Franklin W. Kolk, Dir., Engrg. R&D, American Airlines, Inc., USA.

1015 Hours — New Physics Hall

General Lectures

Physik des Jet-Stream—Walter Georgii, Dir., Deutsche Forschungsanstalt für Segelflug, Institut für Flugforschung, Germany.
The Aerodynamics of Jet Flaps—John Williams, Supt., Low-Speed Tunnels Div., Aerodyn. Dept., Royal Aircraft Establ., UK.

Thursday, 15 September

0830 Hours — New Physics Hall

Magneto Fluid Dynamics

Sub- and Super-Alfvénic Flows Past Bodies—W. R. Sears, Dir., and E. L. Resler, Jr., Prof., Grad. School of Aeronautical Engrg., Cornell Univ., USA.
Aerophysical Studies at Hypersonic Velocities in Free Flight Ranges—C. J. Maiden, Hypersonic Physics Group, Canadian Armament Res. and Dev. Establ., Canada.
Magneto-Fluid-Dynamic Shear Turbulence—Luigi G. Napolitano, Assoc. Prof. of Aerodyn., Univ. of Naples, Italy.
Magnetoaerodynamics in Japan—Isao Imai, Prof., Dept. of Physics, Faculty of Science, Univ. of Tokyo, Japan.

0830 Hours — Small Physics Hall

Structures and Fatigue

Statistical Methods for Fail-Safe Design with Respect to Fatigue of Aircraft Structures—Bo K. O. Lundberg, Dir., The Aeronautical Res. Inst. of Sweden.
A Method of Selfinduced Alternating Loads Alleviation of Airframes—F. Misztal, Prof., Politechnical Univ., Poland.
Einfluss des Start-Landelastwechsels auf die Lebensdauer von böenbeanspruchten Flugzeugflügeln—Ernst Gassner, Laboratorium für Betriebsfestigkeit, and Karl F. Horstmann, Maschinenfabrik Carl Schenk, G. m. b. H., Germany.
Protection of Aircraft Structures Against High Temperatures—Wilfred M. Dukes, Ch. of Struc., Aero-Space Dept., Niagara Frontier Div., Bell Aircraft Corp., USA.

1400 Hours — New Physics Hall

Flows With Chemical Reactions

Limites en Vitesse et Altitude des Propulseurs Utilisant l'Air Atmosphèrique—Albert Gozlan, Chef de Departement (Propulsion), Nord-Aviation, France.
Hypersonic Ramjets—Donald L. Mordell, Dean, Faculty of Engrg., and J. W. Swithenbank, Assoc. Prof. of Mech. Engrg., McGill Univ., Canada.
Research Problems on Recombination and Condensation in Nozzles—Walter T. Olson, Ch. Propulsion Chem. Div., Lewis Res. Center, NASA, USA.
Schliereninterferenzaufnahmen von Kopfwellen und Grenzschichten dissoziierter Gase—Herbert Oertel, Physiker, Deutsch-Französisches Forschungsinstitut Saint-Louis, France.

1400 Hours — Small Physics Hall

Aeroelasticity

Predictions of Lifting Surface Flutter at Supersonic Speeds—Holt Ashley, Assoc. Prof. of Aeronautics and Astronautics, MIT; Walter Mykytow, Asst. Ch., Dynamics Br., Aircraft Lab., Wright Air Dev. Div., USAF; and John Martuccelli, Res. Engr., Aeroelastic and Struc. Res. Lab., MIT, USA.
Elastic Stability and Vibration of Slender Body in Supersonic Flow—Sylwester Kaliski, Prof., and Jerzy Kacprzynski, Master Engr., Dept. of Vibrations, Polish Academy of Sciences, Poland.
Determination des Vitesses Critiques Transitoires d'un Engin Supersonique en Vol Accéléré—Robert Mazet, Prof., Dir. Scientifique, and Eugene Bonneau, Chef de Groupe de Recherches, ONERA, France.
Vibrations of Viscoelastic Plates and Shells due to Rapid Heating—Witold Nowacki, Prof., Polish Academy of Sciences, Poland.

Friday, 16 September

0830 Hours — New Physics Hall

Entry From Space

Manned Re-Entry at Super-Satellite Speeds—Robert B. Hildebrand, Ch., Advanced Syst. Res., Aero-Space Div., Boeing Airplane Co., USA.
Effects of Non-Equilibrium Flows on Aerodynamic Heating During Entry into the Earth's Atmosphere from Supercircular Orbits—Glen Goodwin, Ch., and Paul Chung, Res. Scien., Heat Transfer Br., Ames Res. Center, NASA, USA.
Radiative and Ablation Cooling for Manned Re-Entry Vehicles—Leonard Roberts, Aeronautical Res. Engr., Langley Res. Center, NASA, USA.
Sur l'Aérothermodynamique des Parois Fongibles—Th. Moulin and J. J. Bernard, ONERA, France.

0830 Hours — Small Physics Hall

Aerospace Medicine

Zur Frage der Auswahlmethoden für Besatzungen unkonventioneller Flugkörper—Siegfried Ruff, Prof., Institut für Flugmedizin, Deutsche Versuchsanstalt für Luftfahrt e. V., Germany.
Body Susceptibility to High Accelerations and to Zero Gravity Condition—Rodolfo Margaria, Prof. of Physiology, Institute of Human Physiology, Medical School, Univ. of Milan; and T. Gualtierotti, Institute of Human Physiology, Univ. of Sassari, Italy.
A Review of Biologic Exposures to Space Environments—Brig. Gen. Don Flickinger, Asst. to Commander for Bioastronautics, USAF (MC), USA.
Comportement de Quelques Fonctions Perceptives et Motrices Pendant le Passage de Deaux à Zéro G, Obtenu au Moyen de la Tour de Subgravité. Influence de l'Entrainement—Tomaso Lomanaco, Dir. des Services de Santé de l'Aviation Militaire, Corps de Santé, Aviation Militaire Italienne, Aristide Scano, IAF (MC), and Franco Rossanigo, IAF (MC), Centre d'Etudes et de Recherches de Médécine Aéronautique, Italy.

1400 Hours — New Physics Hall

Space Flight

Power Generation Systems for Use in Space—Henry O. Slone and Seymour Lieblein, Aeronautical Res. Engrs., Nuclear Reactor Div., Lewis Res. Center, NASA, USA.
Guidance of Space Vehicles by Radio Measurements and Command—A. R. M. Noton, Group Supervisor, Jet Propulsion Lab., CIT, USA.
Discoveries from Satellite Orbits—D. G. King-Hele, Prin. Scien. Officer, Royal Aircraft Establ., UK.

CLOSING SESSION

SECTION MEETINGS CALENDAR*

June 7 San Diego: Technical Meeting, IAS Bldg., 7:30 pm, "Doppler Inertial Guidance for High Performance Aircraft", L. S. Reel, Ryan Aeronautical Co.

June 8 Tulsa: Dinner Meeting, Tulsa Univ. Student Activities Bldg., 6:30 pm, Business Meeting, "The Changing Curriculum in Engineering Education", M. R. Lohmann, Dean, Coll. Engrg., Oklahoma State Univ.

June 11 Niagara Frontier: Field Trip, 3 pm, Niagara Power Project, Exhibition Bldg.

June 14 Boston: Annual Thompson Club Mtg., Thompson Club–Nahant, Mass., 6 pm, "Antisubmarine Warfare", RAdm. C. E. Weakley, USN.

June 14 Los Angeles: Specialists Meeting, IAS Bldg., 8 pm, "Bi-Axial Stress Fields", D. Fitzgibbon.

June 14 San Diego: Annual Historical Dinner Meeting, "Development of the V-2", Contact Ruth Staley, IAS Bldg., Phone: CYpress 5-5119, for details.

June 16 Baltimore: Dinner Meeting, Johns Hopkins Univ., 6:30 pm, "Air Force Weapon Systems, Current and Future", A. H. Flax, Chief Scientist, USAF.

June 16 Los Angeles: Dinner Meeting, IAS Bldg., 6 pm, "Space, Science and Survival", A. M. Zarem, Electro-Optical Systems, Inc.

June 16 Omaha: Luncheon Meeting, Officers' Club, Offutt AFB, 11:45 am, "Progress Report of TF-33 Turbofan Engine Development", R. S. Baird, Pratt & Whitney Aircraft.

July 7 San Diego: Technical Meeting, IAS Bldg., 7:30 pm, "Methods of Analysis of a Control System for a Large Flexible Missile", D. Lukens, Convair-Astro.

July 14 Los Angeles: Specialists Meeting, IAS Bldg., 8 pm, "Ion Engine Development", T. Forrester.

July 16 San Diego: Annual Summer Dance and Cruise Aboard Kon-Tiki, 9 pm.

July 21 Los Angeles: Dinner Meeting, IAS Bldg., 6 pm, "Exploring the Sun", L. Larmore, Lockheed Aircraft Corp.

July 21 San Diego: Technical Meeting, IAS Bldg., 7:30 pm, movies with transonic and supersonic theme.

Aug. 18 Los Angeles: Dinner-Historical Meeting, IAS Bldg., 6 pm, "The Evolution of Propulsion", D. L. Walter, The Marquardt Corp.

Aug. 31–Sept. 1 Los Angeles: Section Symposium, IAS Bldg., all day, "Recovery of Space Vehicles"—including Secret sessions.

Sept. 15 Los Angeles: Dinner Meeting, IAS Bldg., 6 pm, "Project Rover", L. Schreiber, Dir. "N" Div., Atomic Energy Commission.

*Items for this section accepted up to seven working days before end of the month.

INTERNATIONAL, NATIONAL, AND JOINT MEETINGS CALENDAR

June 15–17 Heat Transfer and Fluid Mechanics Institute, Stanford Univ., Cosponsored by the IAS.

June 28–Jul 1 Summer Meeting, Ambassador Hotel, Los Angeles, Calif.

Aug. 1–3 Meeting on Future of Manned Military Aircraft, San Diego, Calif.

Sept. 12–16 2nd International Congress, International Council of the Aeronautical Sciences, Zurich, Switzerland.

Oct. 3–5 Midwestern Conference on Air Logistics, Tulsa, Okla.

Oct. 17–18 CAI/IAS Joint Meeting, Queen Elizabeth Hotel, Montreal, Canada.

Oct. 20–21 Symposium on Hypervelocity Techniques, Denver, Colorado.

Dec. 17 Wright Brothers Lecture, Washington, D.C.

1961

Jan. 23–25 29th Annual Meeting, Hotel Astor, Times Square, New York.

Mar. 9–10 Flight Propulsion Meeting (Classified), Cleveland, Ohio.

June 13–16 Summer Meeting, Los Angeles, California.

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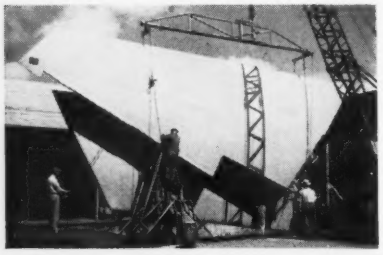
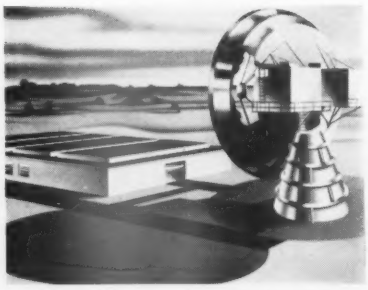
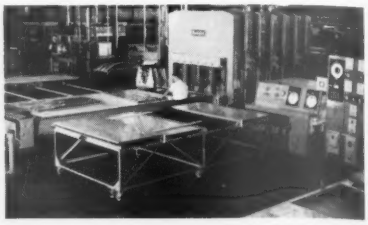


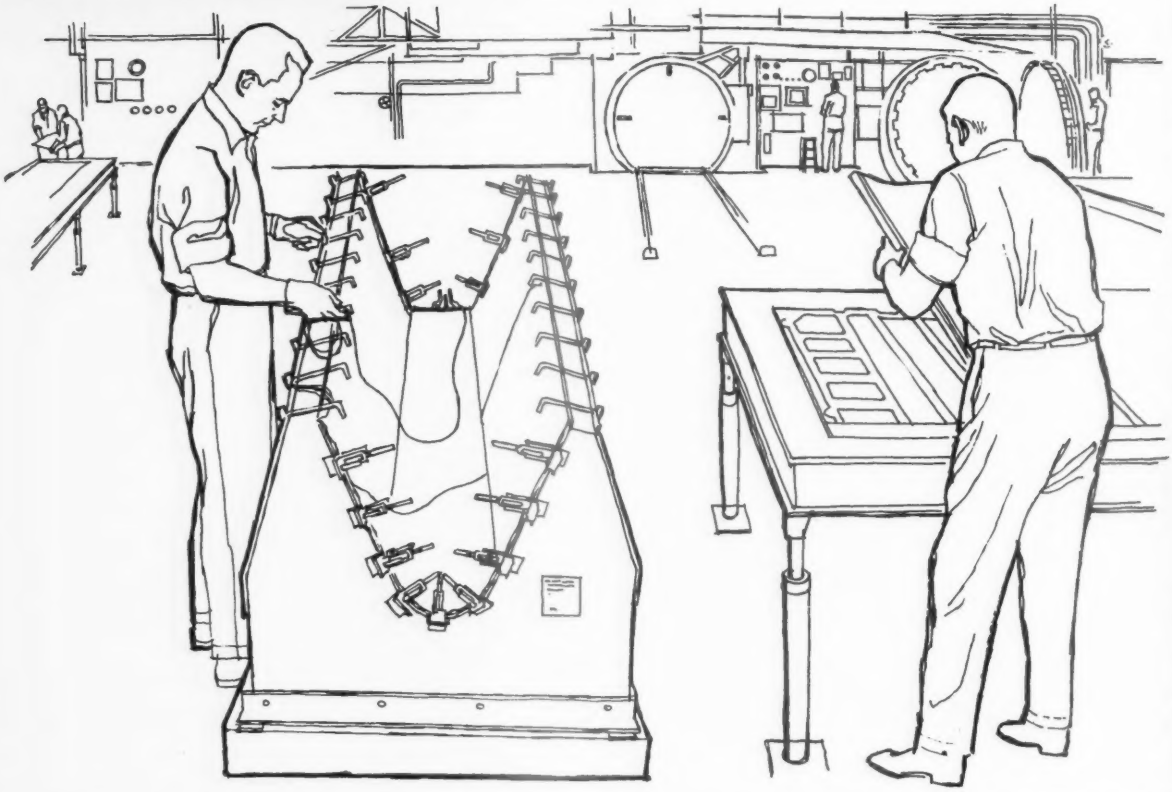


complete in the world—enables Fairchild to perform bonding projects of any scope, size or complexity. Air conditioned, humidity-controlled working areas and stringent quality control assure work of the highest order.

Whatever your construction requirements, there is a Fairchild *performance-proved* bonding method specifically suited to fill them. Write today for information on your needs.



Representative of Fairchild's diverse production capabilities are: VTOL/STOL projects • High flotation gear • Boeing B-52 assemblies • SD-5 surveillance system • Antenna and installation housing for radar • F-27 propjet • Aluminum boats, lampposts and bridges.



FAIRCHILD AIRCRAFT & MISSILES DIVISION
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IAS News

. . . a record of people and events of interest to Institute Members

Future of Manned Military Aircraft Subject of August Meeting

Dr. Herbert York to Address San Diego Conclave

A NUMBER OF top Department of Defense officials and industry leaders are among those scheduled to air problems related to the Future of Manned Military Aircraft at the Institute's subject meeting to be held in San Diego, Calif., August 1-3. The meeting, sponsored by the IAS in conjunction with the U.S. Army, Navy, and Air Force, will encompass varied aspects of Defense Department planning with regard to tactical, strategic, and logistic purposes, state-of-the-art capabilities, and aircraft design. The technical program, consisting of three all-day sessions, will be augmented by static displays, at Lindbergh Field, of current Air Force, Army, Navy, and Marine Corps manned aircraft, along with examples of equipment now under development in Government laboratories.

Dr. Herbert York, Director of Defense Research and Engineering for the Department of Defense, will be guest of honor and principal speaker at the dinner to be held the evening of August 2, at the El Cortez Hotel, meeting headquarters. All luncheons will be informal.

Arrangements for the meeting have been made by a committee of the Institute's San Diego Section, headed by General Chairman William H. Mollering of General Dynamics Corporation's Convair Division. Other committee members include Assistant to the General Chairman Comdr. W. H. Cullin, USN, attached to Dr. York's office; Technical Program Chairman John Hopkins; Arrangements Chairman W. D. Logan; Publicity Chairman C. W. Greaves—all of Convair; Static Display Chairman W. K. Orr, Ryan Aeronautical Co.; and Security Chairman B. L. Grondona of the Navy's BuWeps San Diego office.

The meeting, open to IAS members and Government employees only, is classified Secret with security arrangements under the cognizance of the Navy's Bureau of Weapons. Security forms, to be submitted by July 1, and other pertinent information may be obtained from the IAS Meetings Department at 2 East 64th St., New York. Government employees must obtain security clearance through standard Department of Defense procedures in accordance with appropriate military requirements.

The program is outlined as follows:

Monday, August 1

Chairman: William Littlewood, Vice-President—Equipment Research, American Airlines, Inc.

Economic and Geopolitical Environment Future—John Rubel, Deputy Dir., Defense Research and Engineering, Dept. of Defense.

Requirements and Employment of the Army, Navy, and Air Force—Individual presentations for each branch led by Lt. Gen A. G. Trudeau, USA, Chief of Research and Development; Major Gen. Bruce K. Holloway, USAF, Dir. of Operational Requirements; and Vice Adm. R. B. Pirie, USN, Deputy Chief of Naval Operations—Air. All three lead speakers will be supported by representatives from their respective services.

Panel Discussion—Moderator: Lt. Gen. James H. Doolittle, USAF (Ret.), V-P and Dir., Shell Oil Co. Panel: Generals Holloway and Trudeau, Admiral Pirie, William Littlewood, and three representatives from industry. This session, which will be unclassified, will present a discussion of the day's proceedings.

William H. Mollering
General Meeting Chairman

Dr. Herbert York
Dinner Speaker

Tuesday, August 2

Chairman: Dr. Hugh L. Dryden, Deputy Dir., NASA.

Representatives from Government laboratories—e.g., NASA—will discuss the subelements of Power Plants, Aerodynamics, Structures, and Guidance Systems.

Wednesday, August 3

Chairman: Frank Fink, V-P for Engineering, Ryan Aeronautical Co.

Representatives from private industry will outline prospects in VTOL/STOL, subsonic, and supersonic aircraft design based on the preceding discussions.

Harry Passmore, III, of Convair-Ft. Worth Named 1960 IAS Flight Test Fellow

Harry Passmore, III, of Fort Worth, Tex., is the 1960 winner of the Institute's Flight Test Fellowship. The award, one of the most significant fellowships available in the aerospace engineering field, totals $7,800 and provides for 2 years of graduate study at Princeton University.

Mr. Passmore, 25, is an Aerophysics Engineer employed at the Fort Worth facility of Convair, a Division of General Dynamics Corp. He is engaged in technical analysis (including testing and analyses of test results) of the aerodynamics and dynamic stability of the B-58 capsule escape system. Previously, he held design and drafting positions with Chance Vought Aircraft and Lockheed Aircraft's Georgia Division.

The successful candidate was among 24 whose qualifications were studied by a Board of Award composed of Dr. Hugh L. Dryden (HF), Deputy Administrator, National Aeronautics and Space Administration; Dr. Courtland D. Perkins (F), Assistant Secretary of the Air Force (Research and Development); and S. Paul Johnston, IAS Director.

Mr. Passmore holds a Bachelor of Aeronautical Engineering degree conferred by the Georgia Institute of Technology in 1956 and is concluding work at Southern Methodist University toward his M.S. degree, also in Aeronautical Engineering. He is married and is the father of two children.

The award was established in 1954 to give financial assistance to young, promising aeronautical engineers to build "a solid foundation of advanced technical training in the science of test flight." The 1960 award is the seventh to be given.

Application forms are obtained yearly from IAS National Headquarters in New York in time to meet the March 1 closing date.

Harry Passmore, III
1960 IAS Flight Test Fellow

Paul Burr Named IAS Technical Services Director

Capt. Paul J. Burr, USN (Ret.), has joined the IAS Staff as Director, Technical Services, at IAS National Headquarters.

The Institute's Technical Services Directorate is a newly created staff post responsible for the compilation and distribution throughout all Institute activities of "state of the art" information in all areas of aerospace technology. In this capacity Captain Burr will maintain close and continuous contact with aerospace research and development activities in Government, in industry, and in educational institutions. He will serve as the focal point for activities of the Institute's Aerospace Technology Panels. He will keep all IAS Sections, Student Branches, and publications advised of trends of scientific and technical development in their areas of interest.

Captain Burr, a Naval Aviator with an engineering background, has had over 30 years in aeronautics and allied activities, including 22 in the United States Navy and 8 in industry. He has served in the former Bureau of Aeronautics (now Bureau of Weapons), in the Office of Naval Research, and in the Fleet.

An Associate Fellow of the Institute, Captain Burr is a Past Chairman of the IAS Philadelphia Section and onetime Secretary of the Washington, D.C., Section.

Capt. Paul J. Burr

Melvin Gough Recipient of Air Safety Award

The Laura Taber Barbour Air Safety Award of the Flight Safety Foundation was presented to Melvin N. Gough (F), at a luncheon of the SAE's National Aeronautic Meeting held in New York early in April. Mr. Gough, Director of NASA Operations at the Atlantic Missile Range, Cape Canaveral, Fla., received the award for his activities as Chief Test Pilot and Chief of the Flight Research Division at NASA's Langley Research Center, covering the period 1942 to 1958.

Mr. Gough was cited for formulating techniques "for the safe prosecution of advanced flight research experiments." This is the second honor he has received from the Flight Safety Foundation. In 1956 he received their Distinguished Service Award.

Dr. Dryden Receives President's Award

Dr. Hugh L. Dryden, IAS Honorary Fellow, Deputy Administrator of the National Aeronautics and Space Administration, was recently designated by President Eisenhower as recipient of the President's Award for Distinguished Federal Civilian Service, the highest honor the nation can bestow on its federal career civil servants. Presentation of the award, consisting of a gold medal, was made at a White House ceremony on March 8.

James Kindelberger Honored

James H. Kindelberger, Chairman of the Board of North American Aviation, Inc., and an Associate Fellow of the IAS, was honored by his home state of West Virginia recently, when he received the state's Distinguished Service Medal.

The award, presented by West Virginia's Governor C. H. Underwood, cited Mr. Kindleberger's achievements in the field of military aviation during the past 35 years. Granted only on the recommendation of the military board of the state, the medal is awarded to persons who have made significant contributions to their profession and who have reflected credit on the state.

Promotions at McDonnell

Under a new organizational setup at McDonnell Aircraft Corp., four IAS members were among those appointed to new positions with increased responsibilities.

Robert J. Baldwin (AF), formerly Manager of Systems Engineering, and George S. Graff (AF), formerly Chief Aeromechanical Engineer, were named Assistant Chief Engineers of the Airplane Engineering Division. Former Chief Propulsion Engineer, Helicopter Division, Harold H. Ostroff (AF), was named Chief Staff Engineer, Airplane Engineering Division, and Ralph A. Herzmark (M), previously Propulsion Systems Engineer, was named Chief Propulsion Engineer for the division.

Aviation Pioneer Endows Talbott Award

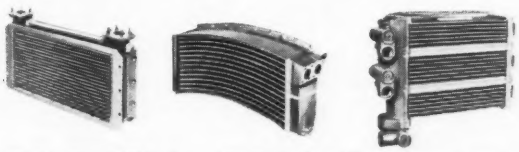
The Cadet Awards Council of the United States Air Force Academy has established The Harold E. Talbott Award for the Outstanding Cadet in Leadership Studies. Made possible by contribution from Grover Loening, an IAS Founder, Benefactor, and Fellow, in memory of Air Force Secretary Talbott, the first presentation of this annual award will be made at the graduation ceremonies this month.

From General Motors . . . Temperatures Made to Order

PROTECTING THE HEART OF THE DELTA DART

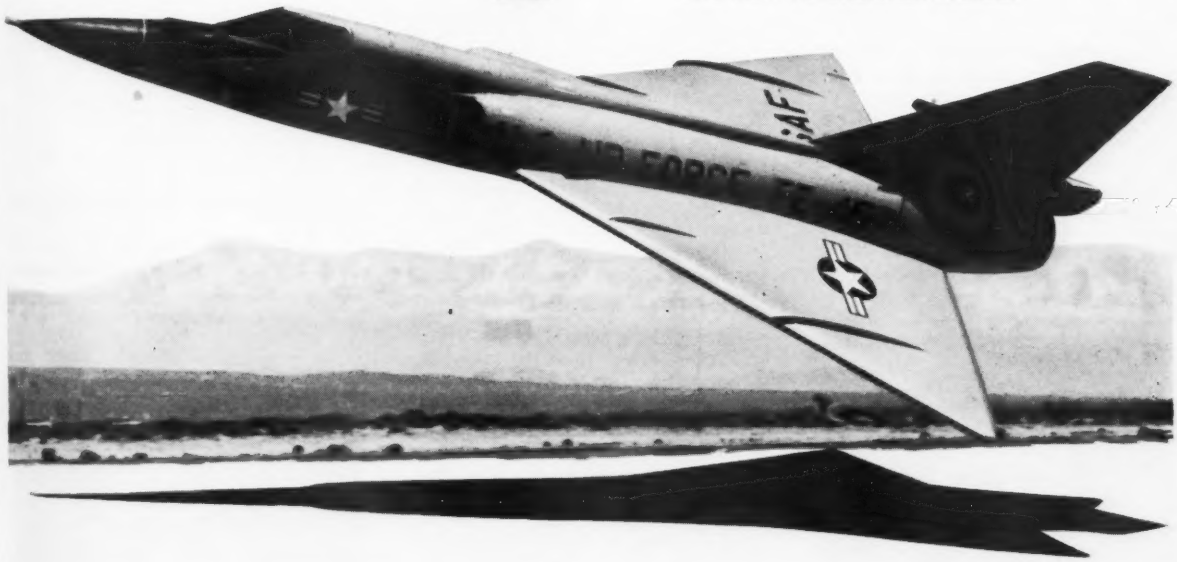
HARRISON HEAT EXCHANGERS PROVIDE DUAL PROTECTION FOR CONVAIR F-106 . . . ALL-WEATHER JET INTERCEPTOR!

In a "red alert" . . . it's scramble and whoosh—altimeters soar above 50,000 ft.—thermometers dive below —50°! The devastating Dart—powered by a Pratt & Whitney J-75 turbojet engine in the 15,000 pound class—carries thousands of pounds of electronic eyes, muscles and brains plus deadly armament on its all-weather missions. Harrison heat exchangers provide dual protection for the Convair F-106 . . . controlling oil temperatures for the engine and the constant speed drive! Guarding vital operating temperatures on today's advanced aircraft is a Harrison specialty. It requires the engineering abilities, the research facilities and long experience in the heat-transfer field inherent in every Harrison product. If you have a cooling problem, look to the leader . . . rely on Harrison for the answer.



Harrison Aircraft Oil Coolers — A Quality Product of General Motors Research

GM PRODUCT RELIABILITY . . .
THE KEY TO GREATER VALUE!



GM HARRISON
TEMPERATURES MADE TO ORDER

AIRCRAFT, AUTOMOTIVE, MARINE AND INDUSTRIAL HEAT EXCHANGERS

HARRISON RADIATOR DIVISION, GENERAL MOTORS CORPORATION, LOCKPORT, NEW YORK

Daniel Guggenheim Medal Presented to Sir George Edwards

Sir George Edwards, Managing Director of Vickers-Armstrongs (Aircraft) Ltd., and an Honorary Fellow of the IAS, received the Daniel Guggenheim Medal at the National Aeronautic Meeting of the Society of Automotive Engineers in April. Jerome Lederer, Director of the Cornell-Guggenheim Aviation Safety Center, made the presentation.

This international aviation award, sponsored jointly by the IAS, SAE, and the ASME, is presented each year for notable achievements in the advancement of aviation. Recipients are selected by a committee of aviation industry leaders.

The Board of Award cited Sir George, one of aviation's most renowned designers and administrators, for "a lifetime devoted to design of military and commercial aircraft culminating in the successful introduction into worldwide commercial service of the first turbine powered propeller-driven aircraft." (Reference is to the Viscount.) Sir George has further contributed to jet transport by supervising the design and production of the Vickers Vanguard and the VC-10.

Jerome Lederer, *left*, presents Daniel Guggenheim Medal to Sir George Edwards.

Necrology

August W. Raspet

Dr. August W. Raspet, Head of the Aerophysics Department of Mississippi State University, was killed in the crash of an experimental plane in Starkville, Miss., on April 27. He was 46 years old.

A graduate of Carnegie Institute of Technology, Dr. Raspet received his M.S. and Ph.D. degrees from the University of Maryland.

He did much original research on sailplanes, applying the results to powered aircraft. His first position with Mississippi State University was as Sailplane Project Leader in which he conducted research on bird flight boundary-layer phenomena and sailplane aerodynamics. He was the author of numerous technical papers, many of which were based on his sailplane studies.

Dr. Raspet was an Associate Fellow of the IAS and a Fellow of the American Association for the Advancement of Science.

1st Lt. Lloyd D. Cogdill (A)
March 16, 1960, Chelmsford, Mass.

Kenneth W. Colman (M)
March 24, 1960, Philadelphia, Pa.

W. A. Klikoff (AF)
April 8, 1960, Los Angeles, Calif.

Harry E. Maloy, Jr. (M)
November 24, 1959, Aberdeen, Md.

Ralph W. Matthews (M)
October, 1959, Atlanta, Ga.

Edward Menasian (A)
February 9, 1960, San Jose, Calif.

IAS *News* — *News of Members*

Donald C. Berkey (M) has been appointed to head General Electric Company's newly formed Large Jet Engine Department's engineering. He was formerly General Manager of the Jet Engine Department.

Claude Brenner (AF), previously Chief Project Engineer, Aeronautical and Mechanical Engineering Division, Allied Research Associates, Inc., has been named Chief Engineer in the company's newly organized Engineering Division.

John C. Brizendine (M) has been appointed to the newly created office of DC-8 Program Manager by Douglas Aircraft Co. He was previously Test Project Engineer for the DC-8 flight-test program.

Capt. Sheldon Brown, USN (Ret.) (AF), has been appointed Assistant Manager, Aerojet-General Corporation's Atlantic Division. Prior to his new position, Captain Brown served as consultant to the General Planning Staff of All American Engineering Co.

Robert P. Brush (AF) has been appointed Assistant Director of International Commercial Sales for Douglas Aircraft Co. Mr. Brush has been on that staff for the past 5 years.

Carl W. Burrows, Jr. (M), has joined Stromberg-Carlson Division of General Dynamics Corp. as Director of Headquarters Sales. Mr. Burrows formerly held this same position with the Military Products Division of Hoffman Electronics Corp.

Thomas D. Carpenter (M) has been named Manager, Future Product Planning for Pesco Products Division, Borg-Warner Corp. Mr. Carpenter was previously Project Manager of the Division's cryogenic program for missile fuel systems.

W. J. Cecka, Jr. (M), has been named Assistant to the President, in charge of the newly established Specialty Products program of North American Aviation's Rocketdyne Division. Mr. Cecka was previously Manager of Engineering Test, Propulsion Field Laboratory, Rocketdyne.

W. C. Cleveland (M), formerly head of Santa Monica Division of Marketing and Requirements for Douglas Aircraft Co., has been appointed Assistant to the Vice-President—Defense Programs.

(*Continued on page 52*)

Major Gen. Victor E. Bertrandias, USAF (Ret.) (A), Vice-President in charge of Sales for Douglas Aircraft Co., has been elected to the board of directors of Transval Electronics Corp.

Daniel J. Fink (AF), formerly Vice-President and Chief Engineer, has been named to head the Research Division of Allied Research Associates, Inc.

EDITORIAL

A New Look for the Staff of the IAS

During the past year we have gone through the exercise of recasting the overall structure of the Institute to make its government more "democratic" and to improve the channels of communication between membership and management. In revising our Constitution we have avoided the pitfall of overorganization that seems to plague some of the older societies. A high degree of flexibility now exists so that, if we keep our collective ears to the ground, we can shift our programs as necessary to meet the changing needs of the membership. This is vitally important in this period of exploding technology.

The continuing expansion of membership and the increasing tempo of activity have imposed strains on the staff setup that have exposed weaknesses in our organizational pattern. These have been examined in detail by Officers and Council and certain changes are in process. The "New Look" for the IAS Staff is laid out on the pages immediately following—a "Who's Who" and "What They Do" under the setup authorized by the Council at the Los Angeles Meeting of April 19.

A serious organizational weakness of the past few years has been the fact that no reserve or "backstopping" has existed for any of our key people. If any one of our top staff had become incapacitated for any reason, we would have been hard-put to perform the services that we owe to our members. It has been obvious for some time that we would be in a much less precarious position if we added a competent "across the board" technical man to our Staff. Such a person would serve a very useful purpose in keeping our scientific and technological know-how up to date. He would serve as the coordinator of the Aerospace Technology Panels to keep IAS program planners and IAS editors tuned in on the "state of the art" and the scientific trends of the times. At the same time such a person would provide much needed "backstopping" for essential staff people.

The general job specification called for someone who was well acquainted with R&D at all levels in Government and in industry, who could deal intelligently with technical people—scientists, engineers, and educators—and who is temperamentally qualified to fit into our kind of organization. We visualized a new staff assignment, a "Technical Services Director," with general functions as outlined above and as detailed in the chart following.

We have been fortunate in finding just such a man to fill this "slot." Captain Paul Burr, USN (Ret.), an old friend of the Institute and a long-time personal friend of many of our members, has joined our Staff in that capacity. Thirty years in aviation (22 in the Navy plus 8 in industry) have given him a background of experience which qualifies him uniquely for this new and important post. An engineer by profession, he has served in ONR, in the old BuAer, and with the Fleet in research and development, logistical support, and operational planning. He has been active in IAS Section activities adjacent to his Duty Stations for

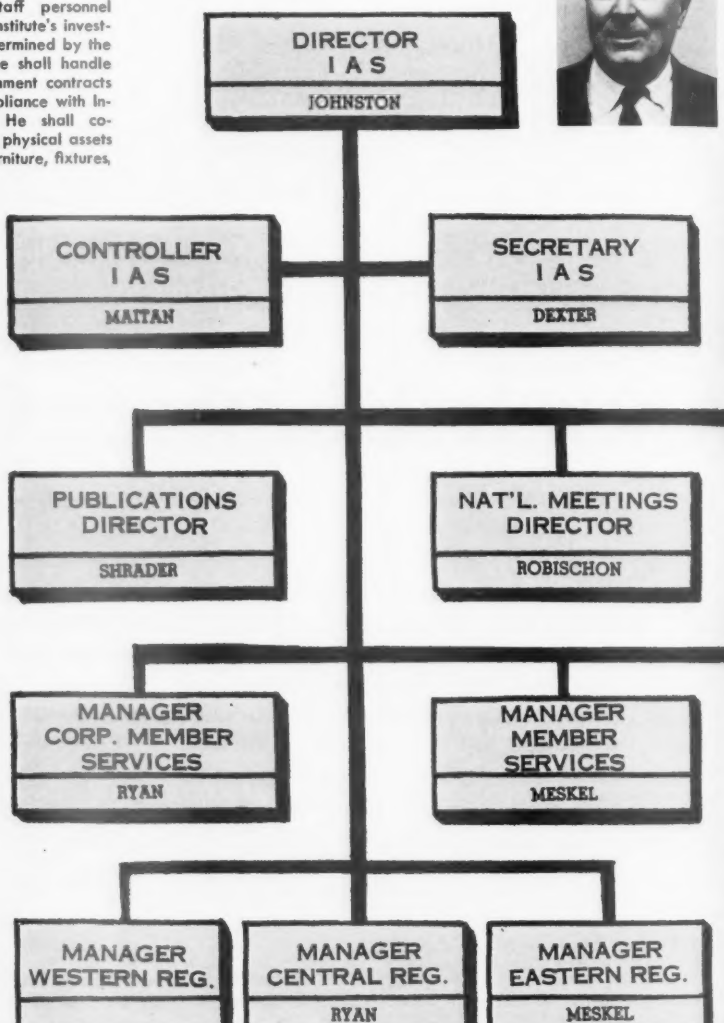
A New Look fo

The DIRECTOR* is responsible for effective and economical management of the Institute in accordance with policy directives laid down by the Council.

The CONTROLLER* shall coordinate all fiscal matters of the Institute. He shall be responsible for the preparaton of budgets, keeping of records and accounts and of Staff personnel records. He shall manage the Institute's investment program under policies determined by the Council's Finance Committee. He shall handle the administration of all Government contracts and be responsible for IAS compliance with Industrial Security Regulations. He shall coordinate the management of the physical assets of the IAS including buildings, furniture, fixtures, and equipment.

The PUBLICATIONS DIRECTOR shall be responsible to the Director for the preparation, publication, and distribution of all Institute publications (except for IAS Papers which are handled by the Meetings Department), in accordance with directives of the Council's Publications Policy Committee....He shall study and approve format and costs of all nonperiodic literature (programs, promotion brochures, vocational guidance manuals, etc.) prepared by other departments of the Institute....He shall be responsible for the sale of advertising in the Institute publications, and for the economic welfare of all publications....He shall be responsible for press and public relations at National Meetings, including the preparation of advance releases, press kits, and press room operations....He shall operate under a budget prepared by himself and approved by the Director.

The MANAGER, CORPORATE MEMBER SERVICES, shall be responsible to the IAS Director for maintaining close and continuous contact with all Corporate Members, visiting them periodically to develop ways and means for improving IAS relations with them (e.g., in connection with library services, publication services, field trips, employment services, dinner and hotel assignments, etc.)....He may solicit Corporate Memberships among nonmember companies provided they meet requirements established by the Council....He shall prepare promotion material relating to IAS Corporate Membership....He shall operate within a budget prepared by himself and approved by the Director.



The MANAGER, MEMBER SERVICES, shall be responsible to the IAS Director for maintenance of all membership records. He shall prepare and process all paper work with reference to applications for membership and regrading for the use of the Membership Committee. He shall maintain proper subscription records for IAS Publications....He shall also be responsible for the coordination of all IAS Section activities (cooperating with Regional Vice-Presidents). He shall assist all IAS Sections in matters of program planning, organization, etc. He shall formulate, publish, and distribute standard operating procedure manuals for the use of Section Officers, and also periodic newsletters for the use of Section Officers....He shall be responsible for the operation of the Institute's Member Placement Services....He shall serve also as Assistant Secretary of the Institute and shall collaborate with the Secretary on matters relating to IAS Awards, etc.

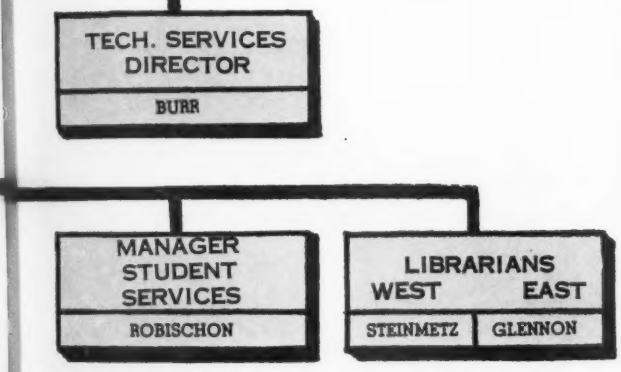
REGIONAL MANAGERS shall be assigned to assist each Regional Vice-President, but responsible to the IAS Director. Such Managers shall handle the necessary administrative work of each region under the direction of the Vice-President, and shall assist him in every way possible in organizing Regional activities....They shall operate under budgets recommended by the Regional Vice-Presidents and approved by the Director.

...the Staff of the IAS

The SECRETARY* shall be responsible for overall coordination and planning for all IAS technical programs (in collaboration with the National Meetings Policy Committee and with the Technical Services Director). He shall be responsible for the coordination of all IAS Member and Student Services, for cooperative activities with other scientific societies at the National level, and for the coordination of all IAS International Programs.... He shall be the custodian of and shall manage all IAS Honors and Awards.... He shall perform other services legally required of the Secretary of the Corporation, and such other matters as the Director may designate.

The NATIONAL MEETINGS DIRECTOR shall be responsible to the IAS Director for the physical organization (including security provisions, if any) and management of all IAS National Meetings, inspection trips, etc. Technical programs will be developed jointly by the Secretary, the Technical Services Director and the appropriate Program Planning Committees, but the promotion, arrangements and operation of the meetings (hotel or other sites, physical setup and equipment, press room facilities, arrangements for luncheons and dinners, etc.) will be the responsibility of the National Meetings Director....He shall be responsible for security procedures, sponsorship, etc., at the National level (excepting National Officer and Staff clearances, and National office facilities clearances which are the responsibility of the IAS Controller).

The TECHNICAL SERVICES DIRECTOR shall be responsible to the IAS Director for the compilation and distribution throughout the Institute of "state of the art" information in all aspects of Aerospace Technology. He shall maintain continuous contact with the R&D elements of governmental agencies, industrial organizations, and educational institutions to keep up to date on scientific and engineering trends affecting IAS programs and shall establish proper channels to keep all elements of the Institute currently advised on matters relating to their particular operations. He shall be responsible for the proper coordination and operation of the Aerospace Technology Panels. He shall maintain contact with the Editors of IAS Publications. He shall coordinate continuously with the IAS Secretary and with Program Planning Committees at all levels and with the IAS Long-Range Planning Committee.



*The Director, the Secretary, and the Controller are elected Officers of the Corporation.

The MANAGER, STUDENT SERVICES, shall be responsible to the IAS Director for all Student Branch and associated activities of the Institute. He shall develop and distribute Standard Branch Operating Procedure Manuals. He shall coordinate his activities with the IAS Educational Advisory Committee, The Engineering Career Development Committees, the Regional Vice-Presidents, and the Student Activities Committees of the Section....He shall be responsible for the organization and operation of all Regional Student Conferences. He shall coordinate the selection and awarding of prizes under the Minta Martin Aeronautical Student Fund.... He shall operate the IAS Film Library and Film List....He shall edit and produce the "IAS Student News" with the advice of the Publications Director....He shall operate under a budget prepared by himself and approved by the Director.

LIBRARIANS, WEST AND EAST, will be responsible to the Director for the effective management of their respective libraries. In the case of the Pacific Aeronautical Library, however, policy directives and annual budgets will be prepared, as at present, by PAL Advisory Management Committee. In New York, the Librarian is also responsible for the proper preservation of the historical material in the Institute's Archives (except for the Los Angeles Durand Museum, which comes under the supervision of the Western Region Manager).

IN THE OVERALL, we perform our basic mission—the interchange of scientific and technical information—by means of Meetings and Publications. Two large segments of IAS operations are concerned in these areas. In addition, and cutting across at all levels, is the problem of providing proper scientific or technical direction for all our activities. This requires constant attention to trends and constant revision of program planning to keep ahead of the professional needs of our members, to anticipate their need-to-know requirements.

After a careful survey of the several services we render to our membership, we have evolved the above staff pattern designed to handle current operations efficiently and capable of expansion to meet future requirements. This has been approved by the Council.

many years. He was one-time Chairman of our Philadelphia Section, later Section Secretary in Washington. He knows us, and we know him. We are glad to have him aboard.

Recently, IAS President Don Putt suggested that the National Meetings responsibility has now grown to the point to warrant specific assignment to a single staff member. Accordingly, a new staff job, "National Meetings Director," with duties as outlined in the preceding page, has been set up. E. W. Robischon will be transferred to New York to take over this assignment. He will be assisted by John Bidwell, who has been doing a very fine job handling meetings details in the New York Office for the past several years. For the time being, "Robie" will be wearing two hats. He will also function as "Acting Manager, Student Services." In this department he will be assisted by Anthony Harris, who has been with us since the Spring of 1959 and has been doing an outstanding job in handling many of the details of our Student Programs and publications.

Tom Meskel will continue in his dual role of Assistant IAS Secretary and Manager, Member Services. His former student branch responsibilities have been shifted to the Student Services Department, but he is taking on the additional duty of "Acting Manager, Eastern Region," assisting Regional Vice-President Charles Tilgner.

The Publications Policy Committee of the Council under Dixon Speas has been studying certain far-reaching changes in the IAS publications program to bring our magazines more nearly into line with members' wishes, as disclosed by the Readership and the Professional Interest Surveys of 1959. The Committee met in Los Angeles on the evening of April 18 and the next day presented the following report to the Council.

"The Committee has studied and reviewed the following recommendations which have been developed by staff members responsible for the publication program:

(1) All abstracts and IAS news items to be removed from *Aero/Space Engineering* and the technical article content increased by approximately 100 per cent....

(2) A new publication, *IAS News*, to be issued monthly. This publication will be in the form of an attractive, neat, low-cost, monthly newsletter which can be issued expeditiously. No advertising is presently contemplated.

(3) A new abstracts publication to be originated which will expand upon the present abstracts being presented in *Aero/Space Engineering*. These abstracts are presently financed in part by USAF funds. An application has been made to the National Science Foundation for substantial funding to help support the inauguration of this expanded service.

(4) The membership roster which is now integrated into a regular monthly issue of *Aero/Space Engineering* to become a 13th issue of *Aero/Space Engineering* starting in 1961.

"The Committee has reviewed in detail the . . . above-recommended changes to IAS publications. We recommend to the Council that . . . the Staff be empowered to carry out the recommendations."

After discussion of the report presented by Chairman Speas, the Council unanimously adopted the recommendations of the Committee. The planning for the above revisions in our publications is now under way, and it is expected that the recommended program will be implemented within the next few months. We will begin by increasing the editorial content of *Aero/Space Engineering* and shortly thereafter will begin publication of the separate newsletter.

Meanwhile, we have been exploring ideas for improving the economic outlook of the publications. We have long been aware that, in order to meet today's "cut-throat" competition for advertising support, we would be forced either to expand our own sales staff materially or to retain some outside organization to handle the job for us. After long negotiation and study, a contract has been drawn with John Cockerell, Inc., of Chicago to take over and to handle all IAS advertising sales and promotion under Welman Shrader's supervision.

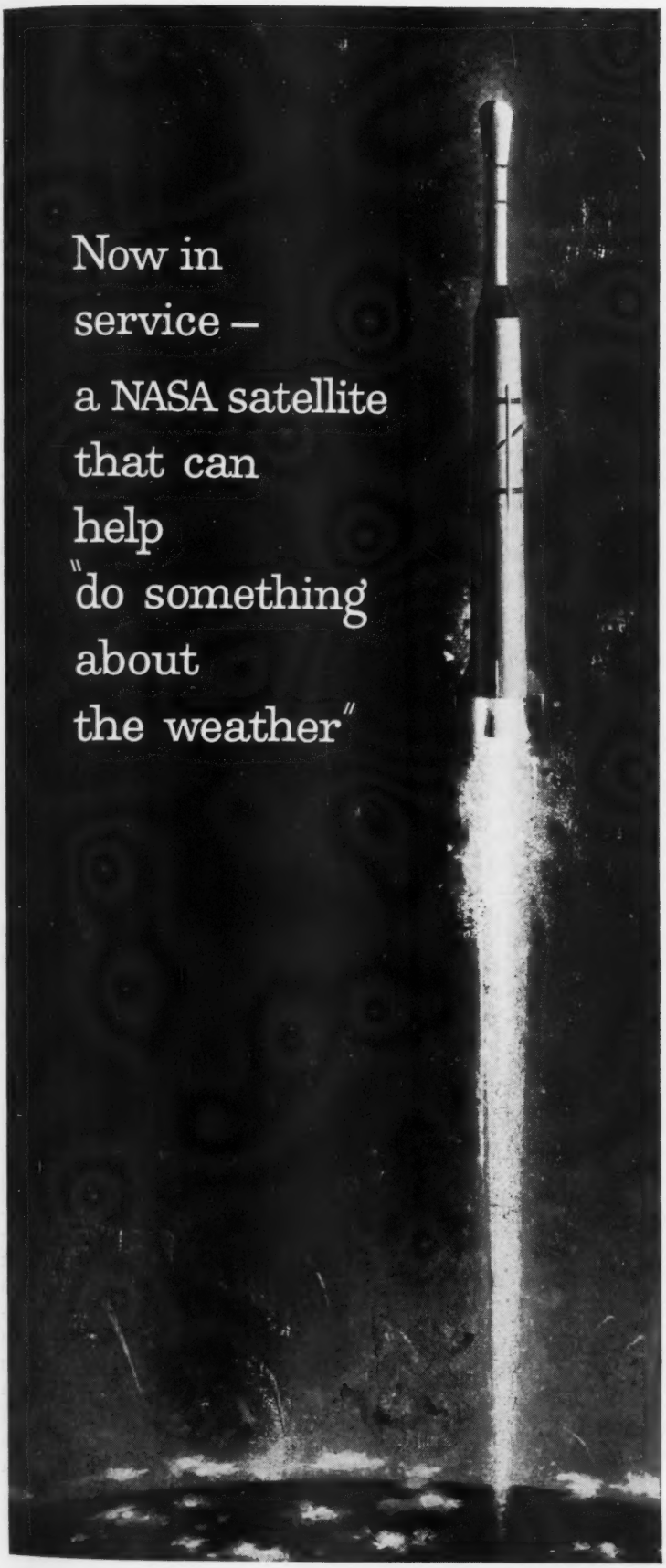
Under this arrangement, Joe Ryan who for 12 years has been Advertising Manager for the *Review* and for *Aero/Space Engineering* will be free to become "Manager, Corporate Member Services," with general duties as shown on the chart. His experience with us makes him well fitted for this important job. Joe will "double in brass" for the time being as "Acting Manager, Central Region" assisting Regional Vice-President Paul Dane.

As indicated on the chart, *press* relations are the responsibility of the Publications Director. On the larger question of Public Relations, we have been in touch with a professional consultant group in this field, and their suggestions will be considered by a special committee of the Council.

All these changes will not come about overnight. The Council ratified the new program at the Los Angeles Meeting on April 19. Paul Burr's assignment became effective as of that date, and he is now a full-fledged IAS Staffer. "Robie" will not come East until early October. Meanwhile, he will be breaking in a replacement in the Western Region. (At this time no new Western Region Manager has been named. He will be nominated by the Vice-President, Western Region, with the approval of the Regional Advisory Committee.) Joe Ryan will continue his regular sales activities until the Cockerell contract becomes effective.

We are, however, now well on the way. It is anticipated that all new assignments will be "phased" into the system by the end of the calendar year. We are certain that these rearrangements will result in a great improvement in our capacity to serve the professional needs of our membership.

SPJ



Out of Space Age achievements by Government and Industry will come better living for everyone

Someday soon the art of weather forecasting will become more precise as the result of a network of meteorological satellites. Even weather *control* may become possible.

The first of these satellites, *Tiros I*, is already transmitting pictures of weather around the world. The booster that helped put it in orbit was a modified version of the reliable Douglas *Thor* IRBM. *Thor* is prime booster in the scientific "Discoverer" firings . . . has worked perfectly in over 85% of its space missions.

Thus the knowledge gained through the development of missiles has a useful peaceful application through NASA projects.

Thor is one more proof that Douglas' extensive experience in missiles is a national asset, and that nothing can substitute for the imagination, experience and skills which Douglas has accumulated in nearly 20 years of missile development.

TIROS (Television Infrared Observation Satellites) would serve weather observers—relaying information on cloud cover, temperatures, solar radiation

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Refractory Materials

Part I—Technology and Low-Temperature Behavior

Part I deals with the general technology of refractory materials—that is, their availability, methods of extraction, consolidation to primary shapes, and fabrication to secondary shapes and end items. The stability of the refractory materials (thermodynamic, chemical stability in service environments, and thermal stability after use) is discussed in general terms. Last, the mechanical behavior at low temperatures, particularly the low-temperature brittleness problem, is discussed.

Part II, to be presented in the July issue, will deal with mechanical behavior at elevated temperature and will discuss the physical properties important in controlling thermal stresses developed in the structural applications. The general course of future trends for these materials will be discussed.

Robert I. Jaffee and Daniel J. Maykuth

Battelle Memorial Institute

UNTIL RECENTLY metallic materials were mainly considered for airframe and propulsion structures. Technical requirements for materials in advanced applications have become so broad that it is now essential to consider nonmetallic as well as metallic materials. Since most information on structural properties relates to metals, and this is the authors' field of specialization, materials as a general class will be considered in this two-part presentation, using metals as a frame of reference.

Compositions

The cutoff in melting point between refractory and nonrefractory materials will be selected at 1,800°C. This has been done to include as refractory materials chromium as a metal, molybdenum disilicide as an intermetallic compound, and titanium dioxide as an oxide. On this basis, the 122 refractory materials shown in Fig. 1 are available for consideration. They include graphite, 12 refractory metals, 18 carbides, 13 oxides, 12 nitrides, 17 silicides, 19 borides, 22 sulfides, and 8 intermetallic compounds. Inclusion of alloying and other alterations in the base composition of the refractory materials will make the list even larger. Obviously, we cannot more than touch briefly on the important problems and comparisons between the groups of refractory materials, and point out properties pertinent to structural applications by which each is characterized. Also, it should be noted that, although reasonably complete information is available on graphite, refractory metals, and oxides, relatively little information pertinent to structural applications is available on the other materials.

Availability

The availability of refractory materials can best be considered from the point of view of the metals and metallic components of the compounds concerned. The nonmetallic components—oxygen, nitrogen, carbon, silicon, and sulfur—are so abundant as to warrant no concern about their availability. Boron and both components in intermetallic compounds will be considered as metals in this connection. Also, for the purpose of this discussion, availability will be taken as the potential availability of the material, not current production. The potential availability will be taken as that amount of material that is or could be made available, through a lead time of 2 to 3 years, given a satisfactory price for the raw material. Five groups, based on a geometric progression, will encompass the availability of the refractory materials, as follows:

Abundant (over 10 million lbs. per year):
Columbium, chromium, molybdenum, vanadium, tungsten, and compounds based on aluminum, boron, magnesium, nickel, titanium, and zirconium.
Good (1 to 10 million lbs. per year):
Tantalum and compounds based on beryllium, cerium, thorium, and uranium.
Fair (0.1 to 1 million lbs. per year):
Hafnium and compounds based on lanthanum and yttrium.
Poor (0.01 to 0.1 million lbs. per year):
Rhenium.
Miniscule (0.001 to 0.01 million lbs. per year):
Iridium, osmium, rhodium, and ruthenium.

Special reference should be made to the fact that some refractory metals are being produced in quantities vastly smaller than their potential. These include rhenium, where only a few hundred pounds per year have been produced, and columbium, where there are vast reserves of pyrochlore deposits, but the relatively small amount of metal being produced is derived from columbite, which is available in much less quantity. The extraction of columbium from pyrochlore is difficult but has already been worked out on a pilot-plant basis.

Extraction and Processing

The refractory metals include many that are very reactive and difficult to extract from their ores in pure form. However, great progress has been made in the extraction of these metals, and it can be stated that all can be produced in a very high degree of purity. Most of the work on extraction is concerned with developing economical methods of producing the material with high purity. The major problems in producing many of the refractory compounds are in achieving stoichiometry, particularly in carbides, and in preparation in a pure condition. Prior to the consideration of refractory nonmetallics as structural materials, purity and mechanical properties generally were secondary to economic considerations. For current applications, higher processing costs could readily be tolerated if improved properties and structural performance were obtained.

Dr. Jaffee, Chief of the Nonferrous Physical Metallurgy Division at Battelle, has for the past decade been closely associated with research on unfamiliar metals. He holds a B.S. from the Illinois Institute of Technology, an M.S. from Harvard, and a Ph.D. from the University of Maryland. Active in the Alloy Section Groups of the National Academy of Sciences' Materials Advisory Board, Dr. Jaffee is a member of the American Society for Metals; the American Institute of Mining, Metallurgical, and Petroleum Engineers; and the Institute of Metals.

Mr. Maykuth, Assistant Division Chief at Battelle's Nonferrous Physical Metallurgy Division, has been involved in research programs on a number of refractory metals. Author of numerous technical papers, he is a subpanel member of the Refractory Metals Panel of the National Academy of Sciences' Materials Advisory Board. He is affiliated with the American Society for Metals and the American Institute of Mining, Metallurgical, and Petroleum Engineers, and holds a B.S. from the Michigan College of Mining and Technology and an M.S. from Ohio State University.

Consolidation

The refractory metals generally are produced in the form of a powder or sponge, which must be consolidated into a dense form or shape suitable for further processing. Consolidation of metals offers no basic problems. Three major processes are used—powder metallurgy, arc casting, and electron-beam melting.

In the powder-metallurgy process, large ingots may be produced by hydrostatic pressing in a plastic con-

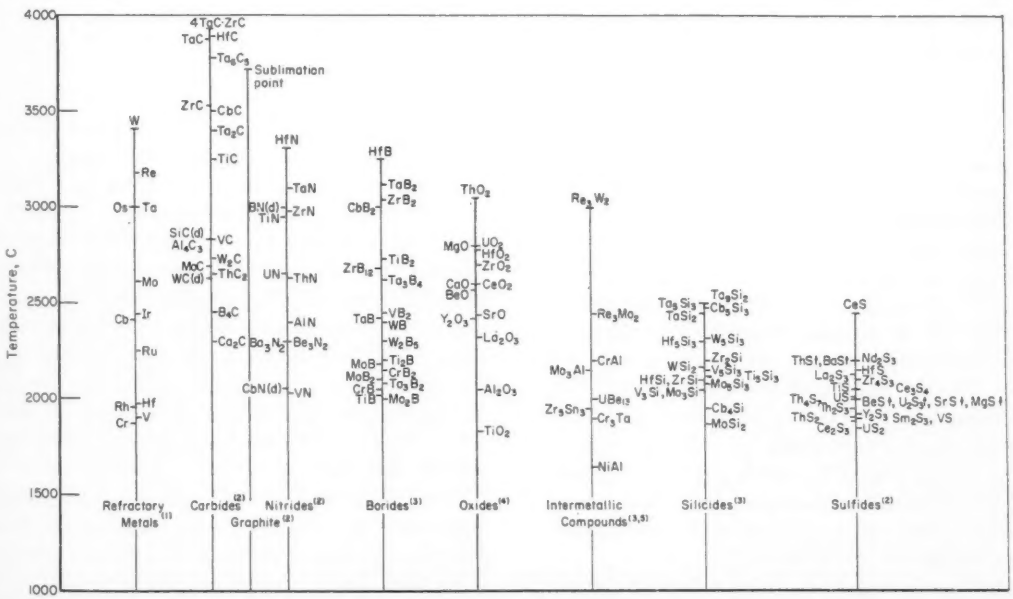

Fig. 1. Melting points of refractory materials.

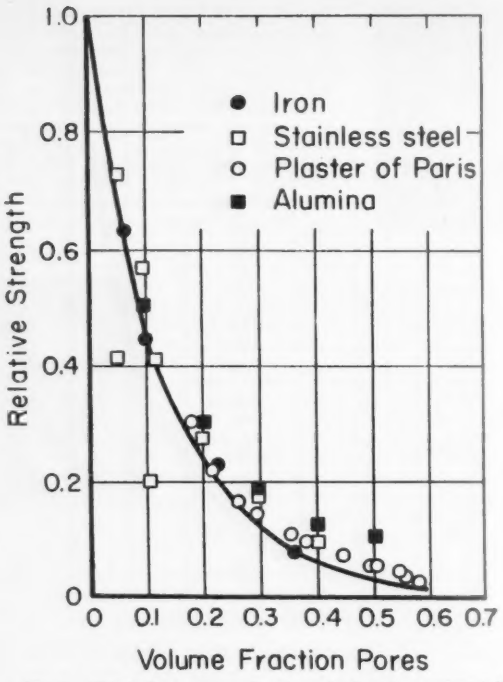

Fig. 2. Effect of porosity on the strength of various materials.[6]

tainer in a high-pressure hydraulic system. Ingots weighing several hundred pounds may readily be pressed by this process. The pressed shapes then are sintered in high-temperature furnaces, using either vacuum, hydrogen, or an inert-gas atmosphere. The sintered ingots may contain up to 10 per cent porosity, but this may be eliminated readily by subsequent hot working, which is facilitated by the fine-grain-size characteristic of the powder-metallurgy billet.

Arc casting is a process developed within the last 10 years for molybdenum and refractory metals. Recently it has been applied to steel and superalloys. Hydrostatically sintered ingots may be used as a consumable electrode in vacuum arc melting to produce ingots 8 to 12 in. in diameter. These may be used as consumable electrodes and remelted to produce a larger ingot of 16 to 24 in. in diameter. The arc-cast ingots characteristically have large grain sizes, and insoluble impurities concentrate at the grain boundaries, making hot working difficult.

A new consolidation method particularly suited for the refractory metals is electron-beam drip melting. In this high-vacuum process, the pressed powder or sponge is fed into an electron gun, which bombards it with highly charged electrons until the metal is molten and drips into a water-cooled copper mold. The first-melt ingot usually has a poor surface and is remelted to produce an ingot with an excellent surface. This process is most used for melting ingots of columbium and tantalum, although considerable development work is being conducted to determine its applicability to other materials.

Consolidation of nonmetallics is a much more difficult problem than with metals, particularly in large section sizes. The major problems are porosity, purity, and brittleness of the sintered material. Porosity has a potent effect on strength, as is illustrated in Fig. 2. As little as 10 per cent porosity will decrease strength by 50 per cent. The same reduction in strength also holds for sintered metals, but porosity may be eliminated from metals by hot working. This is not possible with nonmetallic materials. It is essential to sinter them to practically theoretical density if high strength is to be achieved. The recent development of theoretical-density aluminum oxide, Lucalox, is a case in point. This material has a dense polycrystalline microstructure resembling that of metals, is transparent, and has high strength, although it is lacking in ductility. Also, through use of more sinterable powders, strengths are improved. Usually, nonmetallic materials are pressed dry or suspended in a liquid medium, which is subsequently volatilized. Densification occurs chiefly by diffusion in elevated-temperature sintering. Also, hot-pressing methods and, more rarely, melt-casting methods have been used to reduce porosity. The large grain sizes resulting from casting are disadvantageous to strength, however. Load-bearing members are generally produced by powder processing.

The lack of ductility in nonmetallic materials makes production of large consolidated shapes a risky matter since shrinkage and sintering may be as high as 25 to 50 per cent in volume. Sintering must be done at temperatures high enough, and heating must be uniform, such that the shrinkage stresses will not crack the material. Also, thermal stresses during cooling are such that large sections have to be cooled very slowly to avoid cracking. Compared with metals, the consolidation of nonmetals to theoretical density involves difficulties several orders of magnitude greater. Chiefly, the nonmetallics with low expansion characteristics like graphite or compounds like silica or silicon carbide have potentialities for producing large structural sections which could successfully resist large thermal stresses.

Fabrication

Useful structures are readily fabricated in metals by hot or cold working. Some of the refractory metals, especially tungsten and molybdenum, are sensitive to grain-boundary impurities when they have the large grain size resulting from casting, and require a preliminary hot-working operation involving lateral restraint, like extrusion, to break up the as-cast structure and redistribute the impurities. Following extrusion, these metals may be hot worked in open dies or rolls in a convenient manner. Low-temperature shaping and forming operations are also limited with some of the refractory metals by low-temperature brittleness, which will be discussed later.

Since nonmetallic materials are, in general, not amenable to hot working, shaping is generally done with a vehicle, generally water-based, which is subsequently volatilized during sintering after the part has been molded. Some powders are pressed dry or with a

plasticizer like wax. Another technique is slip casting, where the liquid vehicle is absorbed in a porous mold, instead of being evaporated. This technique recently has been applied to refractory metals, where shapes were desired, and where it would be difficult to hot forge a sintered or extruded billet to the desired shape. Slip castings are sintered to achieve density. The properties of sintered slip-cast refractory metals are not so good as those after hot-working operations because of the detrimental effect of porosity on strength and ductility.

Special shaping techniques are being developed. One of the most interesting is the direct production of sheet from powder by rolling. This technique has been applied successfully to nickel and is being developed for some of the refractory metals. Elimination of intermediate fabrication steps in processing the powder to sheet offers attractive cost-reduction possibilities. Vapor-deposition processes also have been of interest in the production of shapes. An interesting development here is pyrolitic carbon, which is produced by the dissociation of hydrocarbons in a reducing atmosphere. The atom-by-atom vapor deposition results in a dense, columnar structure, which has improved properties as a result of its low porosity. A disadvantage is the relatively large grain size which results in lower transverse strength. Vapor-phase deposition is being used for coatings of borides and silicides. In fact, consideration is being given to the use of this technique for the production of metal sheet.

Joining by fusion methods is a practice almost peculiar to metals and owes its success to the ability of metals to adjust to stress by plastic deformation. In refractory metals, those subject to low-temperature brittleness are limited in their ability to be joined, and mechanical joining methods generally are considered for molybdenum and tungsten. Joining of nonmetallic materials is largely an unexplored area.

Single crystals are produced mostly for research studies. It is on such materials that the recent interesting work on ductile nonmetallic materials has been done. Ductility has been found in single crystals of ionic compounds and cubic oxides, such as MgO.[7] Ductility is somewhat fugitive in that, after exposure to air, a surface reaction occurs, and the crystals no longer remain ductile. At present, the best route to obtaining good structural properties in nonmetallic materials appears to be through achievement of high density and fine grain size and elimination of impurities, which often are the site of crack initiation.

Stability

Various types of stabilities are of importance in characterizing the behavior of materials. First is the thermodynamic stability, which is measured by the free energy of formation. Next is chemical stability in the environment for which the material is to be used. For most purposes, this involves stability against oxygen at elevated temperatures. Last, thermal stability is the ability of the material to maintain its original structural properties after exposure to elevated temperatures under service conditions.

Thermal dissociation occurs when the vapor pressure of one of the dissociation products is less than equilibrium. Some of the platinum-group metals are not oxidized at high temperatures because the dissociation pressure of their oxide is greater than atmospheric pressure. In high vacuum, some of the refractory metals will not oxidize until the partial pressure of oxygen becomes equal to the dissociation pressure. For example, rhenium is not oxidized in vacuum tubes and does not undergo water-cycle transfer until much higher pressures than those for tungsten.

Generally, in refractory-metal oxides, we are not concerned so much with dissociation as with volatilization. The volatilization of oxides occurs readily with molybdenum and tungsten and, to a lesser extent, with the oxides of columbium and tantalum. This makes the oxidation problem of these metals for elevated-

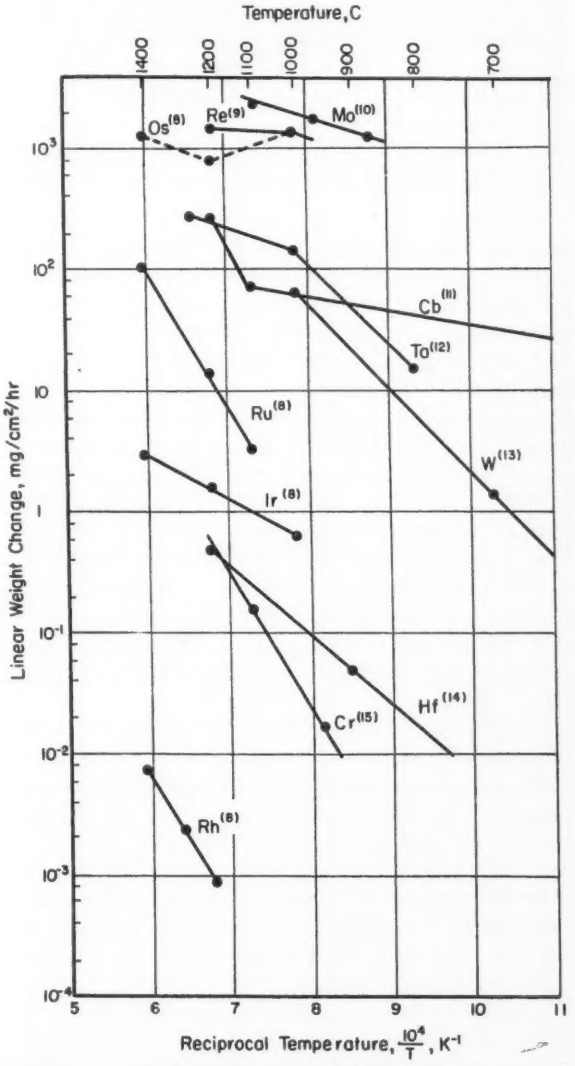

Fig. 3. Oxidation of refractory metals.
(Data for Mo, Re, Os, Ru, Ir, and Rh are weight-loss rates.)

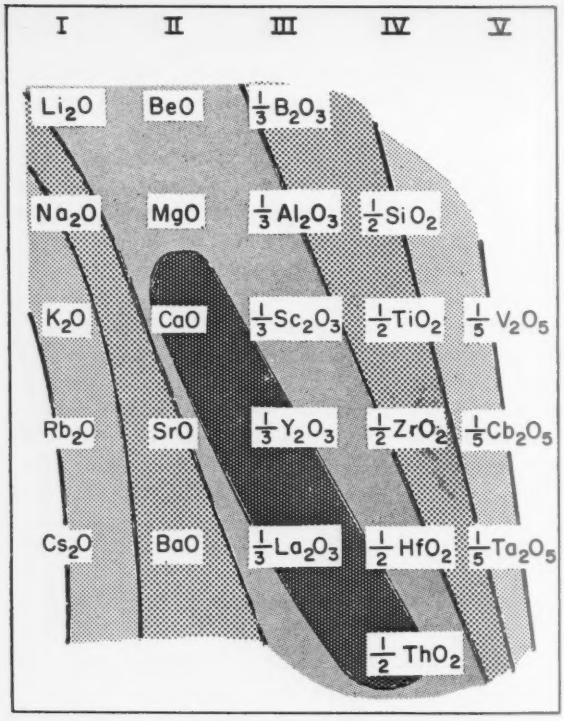

Fig. 4. Stability relationships of refractory oxides.[16] (Solid lines are lines of constant standard free energy of formation from the elements. The darkly shadowed area is the region of greatest stability.)

temperature service more difficult. The high-temperature oxidation rates of the various refractory metals are presented in Fig. 3. Rhodium is the only refractory metal with truly outstanding oxidation resistance at high temperatures. The resistance of chromium is fairly good, but chromium is susceptible to nitrogen absorption unless small amounts of yttrium are present. Iridium and ruthenium are refractory platinum-group metals that oxidize through the formation of volatile oxides. Columbium, tantalum, and tungsten oxidize linearly at elevated temperatures, but their oxides do not melt and become volatile until temperatures somewhat above 1,200°C. are reached. The metals that form low-melting volatile oxides, like molybdenum and rhenium, or highly volatile oxides, like osmium, have oxidation rates fully six orders of magnitude higher than that of rhodium.

Considerable improvement can be made in the oxidation resistance of the refractory metals that have high-melting oxides, including columbium, tantalum, and tungsten. One way this may be done is by alloying with metals of higher valence so as to reduce ionic conduction. Molybdenum or tungsten alloying is moderately effective in reducing the oxidation of columbium or tantalum by this mechanism. Another way is based on the fact that the refractory-metal oxides have a high specific volume in relation to that of their base metal. The oxide cracks and spalls while it is still thin. Alloying with metals whose oxides have smaller ionic radii in the host-metal oxide will reduce the specific volume of the oxide and prolong the time during which adherent protective scales are formed by diffusion. After cracking occurs, oxidation proceeds according to a nonprotective linear time law. Additions of vanadium and molybdenum to columbium are particularly effective because of this factor.

One of the most effective means of improving oxidation resistance is through the addition of elements whose oxides are thermodynamically more stable than that of the base metal. Titanium is particularly effective in a number of refractory-metal bases for this reason. Zirconium is also effective, but less so. Oxidation resistance may be improved similarly by the addition of elements that will form spinels instead of the base-metal oxides. The addition of cobalt and chromium or aluminum and titanium to refractory metals in sufficient concentration to effect the spinel formation has been proved to be effective.

Through alloying, the oxidation resistance of some of the refractory metals has been improved to a degree comparable to that of the nickel-chromiums. Generally, when this is done, other important factors, such as fabricability and elevated-temperature strength, have been lost. Generally, although considerable improvements in oxidation resistance of the refractory metals can be obtained through alloying, it appears that protective coatings will be required to permit these metals to function effectively at projected application temperatures above 1,000°C. The more oxidation-resistant alloys will have an advantage when used in conjunction with coatings in that a defect will not be so dangerous as in a nonoxidation-resistant base.

Considerable work is being done on coating refractory metals for oxidation resistance. Some of the coatings appear to be promising for the conditions involved in the leading edges of re-entry gliders—i.e., short-time exposure at very high temperature. Two cases might be of interest here. In molybdenum, the W-2 coating, a proprietary cementation-type coating applied below the recrystallization temperature, has given successful results in early evaluations. In columbium for protection of leading-edge structures up to 2,500°F., a sprayed ceramic coating with a glassy phase to eliminate porosity and heal defects looks promising for the external surface, and dipped or sprayed aluminum-silicon looks promising for the internal surface. At lower temperatures, up to about 2,000°F., a zinc coating applied by dipping or evaporation looks very promising in that it is self-healing. Coating requirements vary considerably from one application to the next. There does not yet appear to be a satisfactory solution to the more difficult problem of protection of blading for high-temperature turbines, where impact and erosion and longer service times make the coating problem much more difficult than in the leading-edge problem.

The stability of oxides is generally excellent at temperatures up to their melting point, although some become sufficiently volatile at high temperatures to be a matter of concern. Magnesium oxide, for example, dissociates and evaporates rapidly above 1,800°C., considerably below its melting point of 2,800°C.

Kingery[16] has shown, as illustrated in Fig. 4, an interesting plot of the standard free energy of formation of the oxides of the elements as a function of their position in the periodic table. The darkly shaded areas are the regions of greatest stability. It is apparent that the position of the most stable compounds shifts from the lower valence to higher valence groups as the atomic weight increases. Some of the most stable oxides, such as CaO, lose usefulness because of the ease with which they become hydrolyzed by reaction with moisture in air.

Other than oxides, only silicides as a class have good oxidation resistance in air. The higher disilicide is required for good oxidation resistance. The lower silicides oxidize significantly at relatively low temperatures. The disilicides exhibit this property through the formation of SiO_2 on the surface, which is plastic and heals defects, as well as protecting the underlying metal. Most attention has been given to molybdenum disilicide as an oxidation-resistant material. It also is of interest as a coating for graphite and other nonoxidation-resistant refractory materials. Molybdenum disilicide is more oxidation resistant at high than at intermediate temperatures. At about 900°C., the so-called molybdenum disilicide "pest" forms after prolonged exposure.[3]

Graphite has relatively poor oxidation resistance above about 600°C. and requires oxidation-resistant coatings, such as silicon carbide or nitride and molybdenum disilicide, for elevated-temperature use. Porosity aggravates the oxidation of graphite. Dense forms, such as pyrolitic carbon, have considerably better resistance to erosion and oxidation. The poor erosion resistance of graphite in rocket nozzles for solid propellants may be improved by tungsten coatings. It is necessary to provide a barrier between the tungsten and the graphite to avoid the formation of brittle tungsten carbide. One successful barrier is rhenium, which absorbs carbon in solid solution but does not form a carbide.

With the exception of the silicides, nonmetallic compounds—including carbides, borides, nitrides, and sulfides—generally have poor oxidation resistance at elevated temperature. However, some of these compounds have considerable usefulness in nonoxidizing conditions. A few examples might be mentioned. Zirconium boride is extremely inert to molten metals. Cerium sulfide has possible usefulness as a crucible material

Low-Temperature Mechanical Behavior

Metals are characterized by their good ductility. Within the refractory-metal family, there are considerable differences in this property. Fig. 5 presents tensile reduction in area as a function of temperature for the various refractory metals in the recrystallized condition. The highest ductile-to-brittle transition temperatures—i.e., the greatest brittleness—occur with chromium, tungsten, and molybdenum (all Periodic Group VIA metals), which have low solubilities for the interstitially dissolving impurities. The Group V elements are ductile to considerably lower temperatures. They dissolve the interstitial impurities to a greater extent. The transition for columbium can be lowered beyond that indicated by at least another 100°C. through higher purity. The low-temperature ductility of tantalum is so superb that even notched specimens at −256°C. have a reduction in area over 80 per cent. Generally, face-centered-cubic metals do not undergo the ductile-to-brittle transition at low temperatures, although recent data indicate that face-centered-cubic iridium is susceptible to embrittlement up to ~ 500°C. Less refractory face-centered-cubic metals evaluated so far remain ductile at appreciably lower temperatures.

Compared with metals, nonmetals exhibit poor low-temperature ductility. Most polycrystalline oxides, carbides, and nitrides do not exhibit the ability to de-

(*Continued on page 48*)

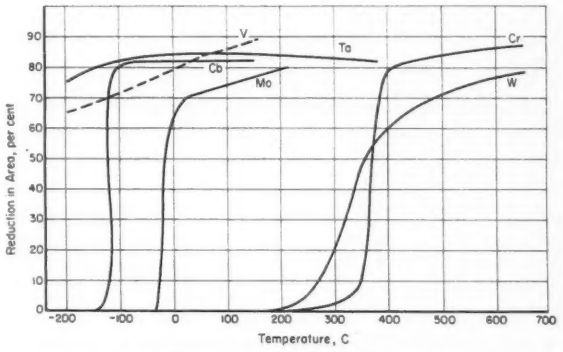

Fig. 5. Tensile transition ranges for recrystallized refractory metals.[1]

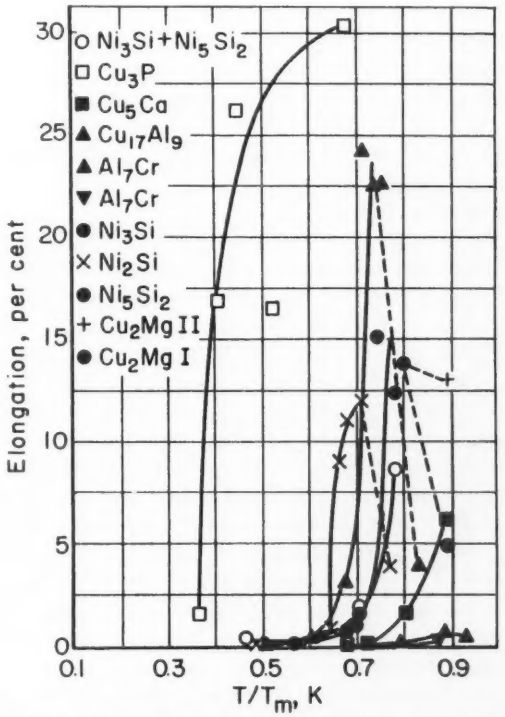

Fig. 6. Tensile elongation as a function of homologous temperature for certain compounds.[3]

This paper reviews the general basic theory of process chemical kinetics with emphasis on its possible application for cooling components of avionic equipments such as packed bed regenerators.

Thermal Application of Catalytic Chemical Kinetic Theory

Alvin R. Saltzman, MIAS

U.S. Naval Air Development Center (Johnsville)

ONE OF THE MOST interesting phases of the work facing cognizant heat-transfer engineers at the U.S. Naval Air Development Center (NADEVCEN) concerns the investigation and establishment of the role that catalytic chemical kinetics can play in the thermal design of avionic equipments.

Present techniques of cooling avionic equipment require that the coolant transfer heat by conventional methods such as convection or evaporation. By means of catalytic reaction techniques, the coolant itself could be made to undergo a chemical reaction. The nature of the reaction selected, endothermic or exothermic, would be such as to provide a favorable temperature condition.

Certain types of electronic components being used in electronic equipments such as airborne computers have a critical low temperature as well as high temperature limit of operation. In some applications, both the high and low temperature limit of operation do not cover the range of temperature extremes called out by military environmental specifications. Despite their limitations, temperature sensitive components are being used because they perform important electronic functions. For applications such as this, it would be of advantage to have a chemical reaction system designed to provide or remove heat at various extremes of environmental temperatures. The temperature of chemical products could be made to exit from the reactor at above or below the temperature of inlet reactants.

By application of chemical kinetic theory, it is possible to provide either an exothermic or endothermic reaction and to increase, maintain constant,

Symbols

A = component A
B = component B
P = component P
C_a = concentration of component A
C_b = concentration of component B
C_p = concentration of component P
H = w^2
F = reactor feed rate, mass per unit time
k = reaction velocity constant
M = $-[(1 + w\eta_{A_0})^2/(\eta_{A_0} - \eta_{B_0})]$
N = $(1 + w\eta_{B_0})^2/(\eta_{A_0} - \eta_{B_0})$
n = order of reaction
η_A = moles of A unconverted per unit mass of feed
η_B = moles of B unconverted per unit mass of feed
η_0 = moles of feed per unit mass of feed
η_t = moles of reacting system per unit mass of feed
p_A = partial pressure of A
p_B = partial pressure of B
q = rate of heat dissipation, B.t.u./hour
R = gas constant in consistent units
r = moles of component A converted per unit time per unit volume. For a second-order flow homogeneous reaction at constant temperature and pressure $r = k[(\eta_A\eta_B\pi^2)/\eta_t^2]$
S = heat-transfer surface, sq.ft.
S_v = space velocity inreciprocal hours
T = temperature, in consistent units
Δt_m = mean temperature difference, °F.
V_r = volume of reactor occupied by reacting system
X_a = moles of reactant A converted per unit mass of reactor feed
z = height or length of reactor
v = moles of product in stoichiometric equation
δ = $v - 2$
π = total pressure
w = δ/η_0

or decrease the temperature of the chemical products formed over reactants. Flexibility of cooling or heating operations could also be achieved since many types of reactions are reversible. Also, side reactions and consecutive reactions, with consequent temperature effects, can be made to occur by proper application of chemical theory. The catalyst itself can also be chosen to be selective in causing a specific type of chemical reaction to occur.

A previous paper (reference 1) on the subject of regenerative heat sinks for airborne electronic equipment pointed out that the packed bed regenerator can be used as a heat storage device operating on a cyclic heating and cooling basis. This same type of component, using catalytic packings, can also be made to serve as a catalytic chemical reactor. The heat dissipated by the electronic components could be transferred to the catalytic packings and used to activate chemical endothermic reactions. An objective of this type of operation would be to have the chemical products exit from the packed bed at a higher enthalpy level but with a desired lower temperature than the original reactants.

At NADEVCEN, cognizant personnel are particularly interested in investigating the range of temperature reductions that can be achieved, the properties of the chemical reactants, products, hardware required, and extent to which the products can be used for additional cooling operations.

This paper on the application of chemical kinetic theory to the thermal design of avionic equipment is to be considered mainly of an introductory nature. In preparing the paper, it was believed that the interest of the reader could best be served by presenting basic theory giving emphasis to heat-transfer aspects of reactor design.

Chemical Kinetics

Kinetics refers to the science of systems in motion. Chemical kinetics deals with the rate of chemical reactions and all the factors that influence them. The science of chemical kinetics can logically be considered as made up of two distinct parts: (1) investigation of the effects of the various process variables upon the chemical reaction rate, resulting in the development of the rate equation, and (2) application of the rate equation to the design of a chemical reactor (reactor design).

With regard to the latter, it should be recognized that when chemical reactions are used to cause desired temperature conditions, the designer is no longer dealing with a conventional heat exchanger but a chemical reactor and all the complex problems associated with reactor design.

Such an approach as indicated above can, however, be likened to the overall approach used in the design of a heat exchanger. The first step is to determine the overall heat-transfer coefficient, and the second is to use the coefficient to size the exchanger.

There are, however, major differences between heat exchanger design and reactor design. The general heat-transfer equation $q = US\Delta t_m$ is applicable to all heat exchanger problems; the chemical reaction rate equation may take a different form for each situation, depending upon the reaction mechanism. Heat-transfer coefficients may be calculated directly from physical properties and flow conditions to good accuracy; reaction rate constants must be experimentally determined for each reaction. Engineers concerned with the design of heat-transfer systems using chemical reactions automatically become interested in the experimental determination of reaction rate equations and rate constants, as well as with their use in the design of reactors.

Mr. Saltzman received his B.S. degree in chemical engineering from North Carolina State College in 1938 and has done further graduate study at New York and Columbia Universities in the fields of heat transfer and fluid flow. He was employed at the U.S. Army Signal Corps Engineering Laboratories from 1940 to 1944 when part of that activity became a part of the USAF. In 1948, he joined the U.S. Naval Air Development Center, Johnsville, Pa., and is now head of the Environmental Analysis Branch of the Aeronautical Electronic and Electrical Laboratory. He has been active in the development of airborne electronic equipment and associated components to give reliable operation under high temperature, as well as other fleet environmental service conditions. He is a member of the American Chemical Society, the IRE, and the IAS.

Mechanisms of Reactions Catalyzed by Solids

The general quantitative relationships involved in the catalysis of fluid reactions by solids are summarized in papers by Hougen and Watson.[3] As a basis for the development of rate equations, it is postulated that, when catalyzed by a solid, a liquid, or gas-phase, chemical reaction actually occurs on the surface of the catalyst and involves the reaction of molecules or atoms which are chemically adsorbed on the active centers of the catalyst surface. The term "active centers" was proposed by Taylor[2] to explain that reactions which are catalyzed by solids actually occur on the surfaces of the solids at points of high chemical activity. The exact nature of an active center and the conditions which must be fulfilled in order that a point on the surface may become an active center remains the subject of much speculation. There is evidence that the interatomic spacing of the solid structure is important as well as its chemical constitution and lattice structure. From this viewpoint, the catalyst increases the rate of reaction through its ability to adsorb the reactants in such a form that the activation energy necessary for reaction is reduced far below its value in the uncatalyzed reaction.

In order that a reactant in the main fluid phase may be converted catalytically to a product in the main fluid phase, it is necessary that the reactant be transferred from its position in the fluid to the catalytic interface, be activatedly adsorbed on the surface, and undergo reaction to form the adsorbed product.

The product must then be desorbed and transferred from the interface to a position in the fluid phase. The rate at which each of these steps occurs influences the distribution of concentrations and temperatures within the system and plays a part in determining the overall rate. Because of the differences in the mechanisms involved, it is convenient to classify these in the following steps when dealing with catalysts in the form of porous particles:

(a) The mass transfer of reactants and products to and from the gross exterior surface of the catalyst particle and the main body of the fluid.

(b) The diffusional and flow transfer of reactants and products in and out of the pore structure of the catalyst particle when reaction takes place at interior interfaces.

(c) The activated adsorption of reactants and the activated desorption of products at the catalytic interface.

(d) The surface reaction of adsorbed reactants to form chemically adsorbed products.

The rates of these four steps of operations are dependent on widely different factors in addition to the concentrations, concentration gradients, temperature and temperature gradients. Step (a) is determined by the flow characteristics of the system such as the mass velocity of the fluid stream, the size of the catalyst particles, and the diffusional characteristics of the fluid. Step (b) is determined by the degree of porosity of the catalyst, the dimensions of the pores, the extent to which they are interconnected, the size of the particles, the diffusional characteristics of the system, and the rate at which the reactions occur at the interface. Step (c) is determined by the character and extent of the catalytic surface and the specific activation energies required for the adsorption and desorption of each of the components of the fluid. Step (d) is determined by the nature and extent of the catalytic surface and by the activation energies required for the reaction on the surface.

In order to calculate the rate at which a catalytic reaction proceeds, it is necessary to develop quantitative expressions for the rates of each of the individual steps which contribute to the mechanism. This requires consideration of the fundamental principles of activated adsorption, surface reactions, mass and heat transfer, and diffusion in porous solids.

It is beyond the scope of this paper to delve into the relative importance of the four steps specified above. The subject is left to the reader with the statement that the relative importance of these four operations in determining the overall rate varies widely depending on operating conditions.

Classification of Reactions

One method in common use emphasizes the phases present, referring to the reaction as homogeneous if only one phase is present, or heterogeneous if more than one phase is involved.

Another method classifies reactions according to the method of operation to obtain the rate, that is, batch or flow. Representative types include batch, semi-batch, and flow, either longitudinal or with complete mixing.

The rate of a chemical reaction is a function of the concentrations of the components existing in the reaction mixture, temperature, pressure, and variables associated with the catalyst. To evaluate these variables, it is desirable to carry out experiments in which a minimum number of variables are changing simultaneously. Carefully obtained experimental data may be used first to determine the form of the rate equation, applicable for the reaction under study, after which the rate constant may be evaluated. The resulting equation and its constants may be used as a basis of equipment design.

Homogeneous Reactions

Homogeneous reactions are commonly studied as either batch or flow reactions. Early investigators in kinetics worked with batch reactions exclusively; the restraint of constant volume was usually satisfied, whether the reaction mass was gaseous or liqiud. Later investigators turned to flow reactions for laboratory investigation. In flow reactions involving gaseous systems, constant pressure conditions prevail. Care must be taken to differentiate between these two modes of operation.

The common method of classifying homogeneous reactions is by the "order of the reaction." If the reaction rate of a constant volume reaction is expressed by

$$r = k_c C_A^a C_B^b \qquad (1)$$

the order of reaction is the sum of a and b, the number and kind of molecules that actually simultaneously combine. The order of a reaction can be determined only from experimental data taken on the reaction itself. Such data may be easily obtained for a batch reaction operating at constant volume. Constant temperature operation is also necessary, because the reaction velocity constant, k_c, changes rapidly with temperature. The data taken are usually the concentration of a key reactant or product at various time intervals during the course of a reaction. Corrigan[5] has summarized the data treatment procedures that may be used to determine the order. Values of k_c, the reaction velocity constant, can be obtained simultaneously.

Many reactions have been conducted in a flow system at essentially constant pressure. The volume occupied by a unit mass of a reaction mixture may vary, thus affecting the concentration of reactants and products. It is for this reason that reactions in a flow system must be treated by using equations involving partial pressures rather than concentrations. In a flow reaction, the reaction rate equation should be expressed as

$$r = k_p p_A^a p_B^b \qquad (2)$$

Before Eq. (2) can be used, it is necessary to express each partial pressure in terms of the same variable—degree of conversion, x. Methods of conversion are as presented in reference 4. The rate constant k_p can be calculated if the value of the rate constant k_c is known from batch data. Hougen and Watson[4] have shown that in general

$$k_p = k_c/(RT)^n \tag{3}$$

where n is the order of the reaction ($n = a + b$).

The pertinent problem in the design analysis of a flow process is the relationship between the reactor volume and the feed rate. This may be determined by consideration of an elementary reactor volume dV_r having the cross-sectional area of the reactor and a length dz in the direction of flow.

For steady state conditions, the number of molecules of A converted in this elementary section per unit time is constant and equal to rdV_r. The material balance of the section requires that this conversion equal the reduction in the number of molecules of component A in the stream passing through the sections. Therefore,

$$rdV_r = FdX_a \tag{4}$$

The required reactor volume for a specified conversion X_a is obtained by integration of Eq. (4) for a constant feed rate

$$\frac{V_r}{F} = \int_0^{X_a} \frac{dX_a}{r} \tag{5}$$

A convenient unit for expressing the relationship between feed rate and reactor volume in a flow process is the space velocity. This is defined as the volumes of feed, measured at standard conditions, per unit time per unit volume of reactor. This unit has the dimension of reciprocal time. For vapor phase reactions, it is convenient to use the symbol S_v to denote the space velocity in reciprocal hours, based on the feed in the ideal—gaseous state at 32 deg. F. and one atmosphere. A convenient simplification results if F is expressed in moles per hour and V is expressed in normal molal volumes. In these units S_v is defined as indicated by Eq. (6).

$$S_v = F/V_r \tag{6}$$

It is possible to design a reactor directly, after the complete kinetic study has been made and the rate equation determined. However, in many cases, it is necessary to include experimental investigations to solve any engineering problems that may arise during the final reactor design calculations.

Heterogeneous Reactions

Many reactions which occur involve more than one phase—reactions in which reactants are actually in different phases and the large group of catalytic reactions in which the catalyst is present in a phase different from the reactant mixture. In this latter case, the simultaneous processes of diffusion between phases and chemical reaction on the catalyst complicate the reaction rate equations and make determination of even an empirical rate equation a complex procedure.

Most of the theoretical process industry developments in the field of heterogeneous catalytic reactions have been limited to gas systems, in which the reactants and products are in a gas phase and catalyst in solid.

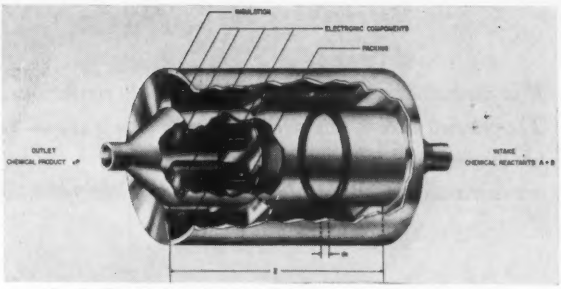

Fig. 1. Chemical packed bed for electronic equipment cooling.

Equations for a homogeneous second-order chemical reaction at constant pressure and temperature:

$$A + B \rightarrow vP \quad \text{(second-order chemical equation)} \tag{1}$$

$$r = k[(\eta_A\eta_B\pi^2)/\eta_t^2] \quad \text{(reaction rate equation)} \tag{2}$$

General Solution of Second-Order Equation

$$\frac{V_r}{F} = \frac{\eta_0^2}{k\pi^2}\left[HX_a + M \ln\left(\frac{\eta_{A_0}}{\eta_{A_0} - X_a}\right) + N \ln\left(\frac{\eta_{B_0}}{\eta_{B_0} - X_a}\right)\right] \tag{3}$$

Modern Reactor Design Techniques

In the past, reactor design involved tedious and expensive experimentation. The key factor is the establishment of a reliable kinetic rate equation using careful experimental procedures. The chemical kinetic equation can then be combined with the basic design equations for material balance, energy balance, heat-transfer rate, and pressure drop, and the system solved simultaneously to give optimum operating conditions and reactor size. Solutions of the equations are involved and time-consuming by conventional techniques. However, electronic computers, both analog and digital, help overcome the mathematical complexity. Fig. 1 depicts an artist's conception of a noncatalytic chemical reaction taking place with the aid of heat energy supplied by the electronic components. Integrated equations for reaction rate, r, and V_r/F are summarized in reference 4. The equations given below and shown also in Fig. 1 are taken from this reference. They cover specifically a second-order type of homogeneous chemical reaction for ideal gases operating at constant temperature and pressure with negligible longitudinal diffusion.

$$A + B \rightarrow vP \tag{7}$$

$$r = k(\eta_A\eta_B\pi^2/\eta_t^2) \tag{8}$$

$$\frac{V_r}{F} = \frac{\eta_0^2}{k\pi^2}\left[HX_a + M \ln\left(\frac{\eta_{A_0}}{\eta_{A_0} - X_a}\right) + N \ln\left(\frac{\eta_{B_0}}{\eta_{B_0} - X_a}\right)\right] \tag{9}$$

(*Continued on page 37*)

It is desired to launch a vehicle into orbit to rendezvous with a satellite. The relative motion between these two bodies is discussed, and steering equations are given for the terminal guidance phase of the maneuver. The resulting trajectories are discussed and illustrated for various initial conditions.

The Long-Time Satellite Rendezvous Trajectory

Louis W. Spradlin

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Mr. Spradlin, Staff Engineer, Instrumentation Laboratory, joined the Laboratory in 1958 upon graduation from the Massachusetts Institute of Technology with a B.S. in aeronautical engineering. His experience has been in the field of automatic flight control systems and includes work in the guidance and control aspects of the satellite rendezvous maneuver. He is presently engaged in graduate study at M.I.T. and will receive an M.S. this month.

TODAY an increasing amount of interest is being expressed in the satellite rendezvous maneuver—that is, launching a vehicle from the earth which will approach a target satellite for the purpose of reconnaissance or replenishment of supplies.

There are four main phases of the overall maneuver:

(1) Precise knowledge of satellite orbit and position.

(2) Launch of the rendezvous vehicle (hereafter referred to as the commuter) into an ascent trajectory whose apogee approaches the satellite orbit at the correct time.

(3) Boost into orbit.

(4) Terminal guidance.

This paper treats the terminal guidance phase of the maneuver. It is assumed that the commuter has been launched and has attained orbital velocity at a certain miss distance from the satellite as the result of errors from phases 1–3. The object of phase 4 is to transfer the commuter from its orbit to the satellite orbit in order to meet the satellite in soft contact fashion. The overall mission is illustrated in Fig. 1.

There are many standard references on the orbital motion of an earth satellite. Most of these, however, treat the motion in terms of components relative to an earth-centered inertial frame. Here, the relative motion between two satellites is of interest, rather than the motion of each satellite relative to inertial space. Thus, for practical reasons, it becomes convenient to observe the relative motion from a coordinate system aboard one of the vehicles. This reference frame was chosen to be a local vertical rectangular axis system centered on the satellite, with the y-axis always directed radially away from the earth's center and the x-axis in the plane of the satellite orbit, as

Symbols

f_x, f_y, f_z	= S-frame components of applied thrust/mass
I_S-frame	= nonrotating coordinate system aboard satellite, aligned with S-frame at $t = 0$
S-frame	= local vertical coordinate system aboard satellite
t	= time
T	= total time required for orbital transfer
T_R	= T-t, time remaining until rendezvous
x, y, z	= S-frame components of distance between satellite and commuter
X_{IE}, Y_{IE}, Z_{IE}	= earth-centered nonrotating axes
$\dot{x}_D, \dot{y}_D$	= S-frame components of desired relative velocity
(ΔV)	= applied change in relative velocity
ϵ	= eccentricity of satellite orbit
ω	= angular velocity of satellite orbit with respect to nonrotating frame

shown in Fig. 2. This is referred to as the S-frame. For the case of a circular satellite orbit, the linearized differential equations of motion—Eqs. (1), (2), and (3)—of a nearby body relative to the S-frame have been derived independently by the author and by others, including Wheelon[1] and Hollister.[2]

When the satellite is in circular orbit, the differential equations of the relative motion are

$$\ddot{x} = 2\omega\dot{y} + f_x \tag{1}$$

$$\ddot{y} = -2\omega\dot{x} + 3\omega^2 y + f_y \tag{2}$$

$$\ddot{z} = -\omega^2 z + f_z \tag{3}$$

The terms in these equations arise from three sources —the applied thrust per unit mass, corrections accounting for the rotation of the coordinate system, and the difference between the acceleration due to gravity experienced by the satellite and the commuter. In reference 2 these equations are derived under the following assumptions:

(1) The earth is spherical and homogeneous.

(2) There is no air drag.

(3) The gravitational field acting on the satellites is due to the earth alone.

(4) The distance between the two vehicles is small compared to the radius of the satellite orbit, permitting the use of perturbation techniques.

For the more general case of an elliptical satellite orbit, the equations are somewhat more complicated because of the eccentricity—Eqs. (4), (5), and (6).

$$\ddot{x} = 2\omega(1 - 2\epsilon\cos\omega t)\dot{y} + (2\epsilon\omega^2 \sin\omega t)y - (\epsilon\omega^2 \sin\omega t)x + f_x \tag{4}$$

$$\ddot{y} = -2\omega(1 - 2\epsilon\cos\omega t)\dot{x} + 3\omega^2[1 - (10/3)\epsilon\cos\omega t]y - (2\epsilon\omega^2 \sin\omega t)x + f_y \tag{5}$$

$$\ddot{z} = -\omega^2(1 - 3\epsilon\cos\omega t) + f_z \tag{6}$$

where $t = 0$ at apogee. To simplify the discussion, only the two-dimensional case will be treated, with the relative motion restricted to the orbital (x, y) plane.

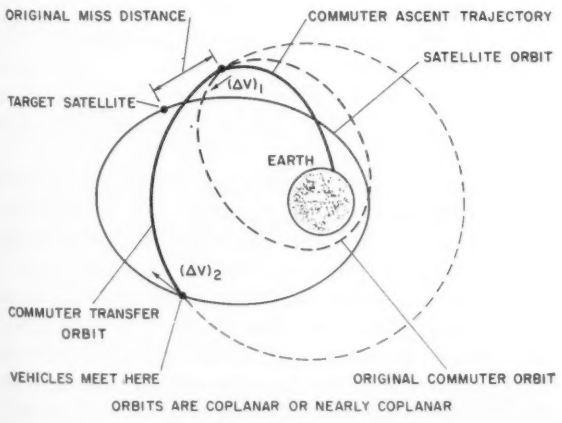


Fig. 1. The rendezvous maneuver.

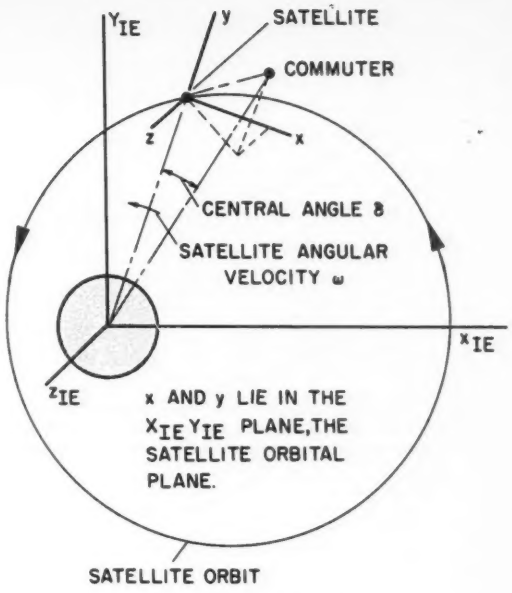


Fig. 2. The S-frame.

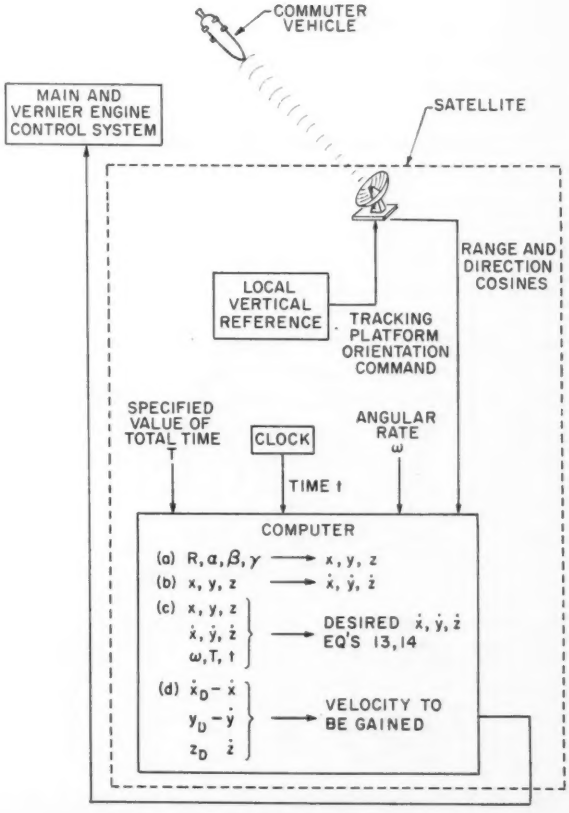
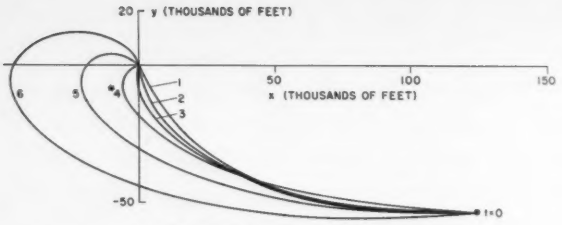

COMMUTER VEHICLE
MAIN AND VERNIER ENGINE CONTROL SYSTEM
SATELLITE
RANGE AND DIRECTION COSINES
LOCAL VERTICAL REFERENCE
TRACKING PLATFORM ORIENTATION COMMAND
SPECIFIED VALUE OF TOTAL TIME T
CLOCK
ANGULAR RATE ω
TIME t
COMPUTER
(a) R, α, β, γ → x, y, z
(b) x, y, z → ẋ, ẏ, ż
(c) x, y, z; ẋ, ẏ, ż; ω, T, t → DESIRED ẋ, ẏ, ż EQ'S 13,14
(d) $\dot{x}_D - \dot{x}$; $\dot{y}_D - \dot{y}$; $\dot{z}_D - \dot{z}$ → VELOCITY TO BE GAINED

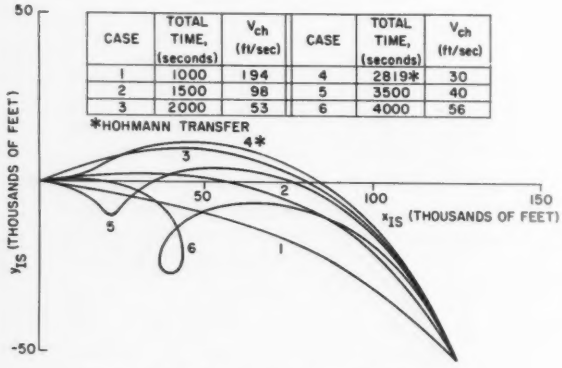
Fig. 3. General steering control configuration.



CASE	TOTAL TIME SECONDS	INITIAL		FINAL	
		$\Delta\dot{x}$	$\Delta\dot{y}$	$\Delta\dot{x}$	$\Delta\dot{y}$
1	1000	-69.5	-19.8	39.4	-114.9
2	1500	-32.1	- 9.7	2.0	-63.8
3	2000	-19.4	- 1.7	-10.6	-31.3
4	2819*	-15.3	0	-14.8	0
5	3500	-16.4	- 5.7	-13.7	17.9
6	4000	-17.8	-15.7	-12.3	29.2

*HOHMANN TRANSFER

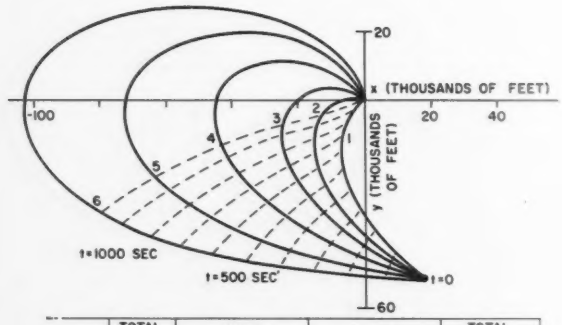
Fig. 4. Transfer trajectories as they appear in the *S*-frame. (Transfer from 290-mile altitude orbit to meet a satellite in a 300-mile orbit with initial separation necessary for Hohmann transfer.)



CASE	TOTAL TIME, (seconds)	V_{ch} (ft/sec)	CASE	TOTAL TIME, (seconds)	V_{ch} (ft/sec)
1	1000	194	4	2819*	30
2	1500	98	5	3500	40
3	2000	53	6	4000	56

*HOHMANN TRANSFER

Fig. 5. I_s-frame trajectories corresponding to Fig. 4.



CASE	TOTAL TIME T, (SECONDS)	INITIAL		FINAL		TOTAL CHARACT. VELOCITY-fps
		$\Delta\dot{x}$	$\Delta\dot{y}$	$\Delta\dot{x}$	$\Delta\dot{y}$	
1	1000	3.7	70.0	-33.0	-24.5	111
2	1500	-0.4	58.0	-29.0	4.9	87
3	2000	-6.4	48.0	-23.0	19.1	78
4	2819	-14.6	29.9	-14.7	29.8	67
5	3500	-19.4	12.5	-9.9	35.8	60
6	4000	-22.1	-3.0	-7.2	41.9	65

Fig. 6. Transfer trajectories as they appear in the *S*-frame. (Transfer from 290-mile orbit to 300-mile orbit. Initially, commuter is only 3 miles behind target, instead of 25 miles as in Fig. 4.)

Also, it will be assumed that the satellite is in a circular orbit.

The transfer maneuver is performed by the application of two thrust impulses, which produce step changes in the commuter's velocity—initially and at the completion of the maneuver—as shown in Fig. 1. The resulting *S*-frame trajectory of the commuter can be calculated by considering the initial conditions of velocity ($\dot{x}_o$, $\dot{y}_o$) to be those measured at $t = 0^+$, after the first thrust impulse. The result is an unpowered, or coasting, trajectory which can be calculated from the differential equations of motion since $f_x = f_y = 0$. The equations for x and y as functions of time and initial conditions are

$$x = [x_o + (2\dot{y}_o/\omega)] - (2\dot{y}_o/\omega)\cos\omega t + [(4\dot{x}_o/\omega) - 6y_o]\sin\omega t + (6\omega y_o - 3\dot{x}_o)t \quad (7)$$

$$y = [4y_o - (2\dot{x}_o/\omega)] + [(2\dot{x}_o/\omega) - 3y_o]\cos\omega t + (\dot{y}_o/\omega)\sin\omega t \quad (8)$$

The components of the relative velocity are

$$\dot{x} = 2\dot{y}_o \sin\omega t + (4\dot{x}_o - 6\omega y_o)\cos\omega t + (6\omega y_o - 3\dot{x}_o) \quad (9)$$

$$\dot{y} = (3\omega y_o - 2\dot{x}_o)\sin\omega t + \dot{y}_o\cos\omega t \quad (10)$$

Consider the transfer trajectory as it appears in the *S*-frame. It can be seen that the motion in the *S*-frame is an ellipse whose center is moving with time according to the last term of Eq. (7). Also, note that the x-coefficients of the sinusoidal terms are twice the magnitude of those in the equation for y, so the major x-axis is twice the magnitude of the minor y-axis for all initial conditions. The period of the ellipse is $2\pi/\omega$, the orbital period of the satellite. The transfer trajectory, as seen in the *S*-frame, is a portion of this ellipse.

The value of $(\Delta V)_1$ required to cause the orbits to intersect in the desired manner can be calculated. In terms of the *S*-frame trajectory, the requirement is that x and y become zero at the same time. Call the time of intercept T, the total time; by specifying that $x(T) = y(T) = 0$, the necessary values of $\dot{x}_o$ and $\dot{y}_o$ can be calculated from Eqs. (7) and (8), as follows:

$$\dot{x}_o = \frac{14y_o(1 - \cos\omega T) - (6y_o\omega T + x_o)\sin\omega T}{(8/\omega)(1 - \cos\omega T) - 3T\sin\omega T} \quad (11)$$

$$\dot{y}_o = \frac{y_o(3\omega T\cos\omega T - 4\sin\omega T) - 2x_o(1 - \cos\omega T)}{(8/\omega)(1 - \cos\omega T) - 3T\sin\omega T} \quad (12)$$

For a given satellite orbit, these values are functions of the total time and the initial position of the commuter relative to the satellite. Note that the denominator in Eqs. (11) and (12) vanishes for ωT equal to 0 or a multiple of 2π; under these conditions, it would require two infinite impulses to effect a rendezvous. This discussion, however, will treat only those transfers whose total time is less than one orbital period of the satellite.

$(\Delta V)_1$ is the velocity-to-be-gained at $t = 0$, and, if

the applied thrust impulse is exactly correct, the paths will intersect at the specified time T. When necessary, vernier corrections to the trajectory can be made through the use of steering equations which give the components of desired velocity at time t.

$$\dot{x}_D = \frac{14y\,(1 - \cos \omega T_R) - (6y\omega T_R + x) \sin \omega T_R}{(8/\omega)(1 - \cos \omega T_R) - 3T_R \sin \omega T_R} \quad (13)$$

$$\dot{y}_D = \frac{y(3\omega T_R \cos \omega T_R - 4 \sin \omega T_R) - 2x(1 - \cos \omega T_R)}{(8/\omega)(1 - \cos \omega T_R) - 3T_R \sin \omega T_R} \quad (14)$$

where $T_R = T - t$, the time remaining until rendezvous.

Fig. 3 illustrates a possible method of mechanizing the steering control, showing tracking and computing equipment on board the satellite. However, if the equipment is placed on the commuter instead, only small errors should be caused by the misalignment of the commuter's local vertical coordinate system relative to the true S-frame, for which these equations were derived. This steering program is designed to produce an essentially coasting trajectory which intercepts the target at time T. At that time, a braking velocity increment $(\Delta V)_2$ is added in order to stop the relative motion (soft contact). In practice, the initial and final applied changes in velocity would not be instantaneous, of course, but would consist of finite-length acceleration and braking phases.

It should be pointed out that the method of effecting a rendezvous with the steering equations given here was also derived independently by Clohessy and Wiltshire. In their paper,[3] emphasis was given to the necessary hardware, including radar and attitude control equipment. Here the resulting trajectories are illustrated, and corresponding characteristic velocities are given for various initial conditions of position. I trust that the two papers will complement each other.

Examples

The following examples are given to illustrate the results of the approach outlined above. For various initial positions, several trajectories are computed, each having a different specified total time of transfer, T. The velocity increment $(\Delta V)_1$ is added at $t = 0$, and it is assumed that no further corrections are necessary until time T. A braking velocity increment $(\Delta V)_2$ is then added in order to stop the relative motion. The characteristic velocity is $V_{CH} = (\Delta V)_1 + (\Delta V)_2$.

(1) The target satellite altitude is 300 miles and the commuter's initial altitude is 10 miles below it—290 miles above the surface of the earth. Assume that both orbits are circular and coplanar. The commuter is initially 23.5 miles behind the satellite, the position necessary for a Hohmann transfer at these altitudes.

It is interesting to observe the effect of the total time on the characteristic velocity, as given by curve A of Fig. 8. For example, by increasing the transfer time from 1,000 to 2,819 sec., the characteristic velocity decreases from 194 to 30 fps.

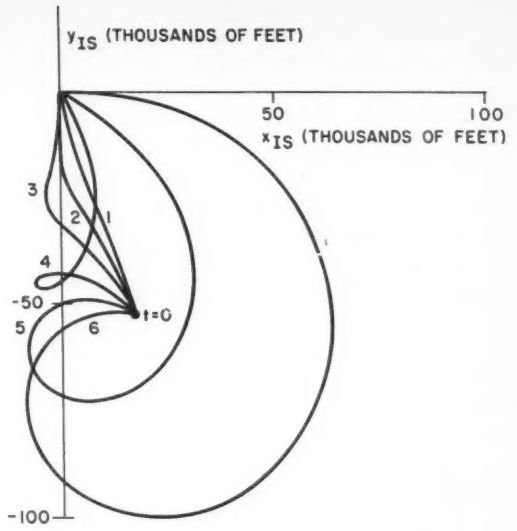


Fig. 7. I_s-frame trajectories corresponding to Fig. 6.

It is also interesting to note the effect of T on the appearance of the trajectories in both the S-frame (Fig. 4) and the nonrotating I_S frame (Fig. 5). As the specified total time is decreased, the I_S frame trajectory approaches a straight line. If it were desired to complete the transfer in a short time, or if the mission were of an intercept-destroy nature, then familiar intercept methods (such as causing the inertial angular rate of the relative range vector to be zero) may be used, provided the magnitude of the closing velocity is sufficient. (A discussion of the short-time satellite intercept problem, including the differential gravitational effect, is given by Hord.[4]) For a long-time satellite rendezvous maneuver, lengthening the transfer time, up to a certain point, will save fuel; after this value of T, however, the fuel requirements increase. But for long-time maneuvers, the I_S-frame trajectories become complicated, and familiar intercept methods do not appear to be applicable for guidance purposes.

(2) For this example both vehicles are at the same altitudes as in Example 1, but the commuter is much nearer initially, only 3 miles behind the satellite at $t = 0$. The S-frame rendezvous trajectories are shown in Fig. 6 and the I_S-frame trajectories in Fig. 7. Although the initial range is less than half that of the first example, for some values of total time T a greater characteristic velocity results. This can be seen from Fig. 8. That the characteristic velocity is a function of initial position, as well as total time, is shown also in Example 3.

(3) It is interesting to compare rendezvous trajectories which have the same total time T but start from different initial conditions of position. For example, consider eight initial positions of the commuter 20 miles from the satellite (Fig. 9). Figs. 10–12 illustrate the trajectories for transfer times of 500, 2,000, and 4,000 sec. Notice the similarity between trajectories corresponding to initial conditions which

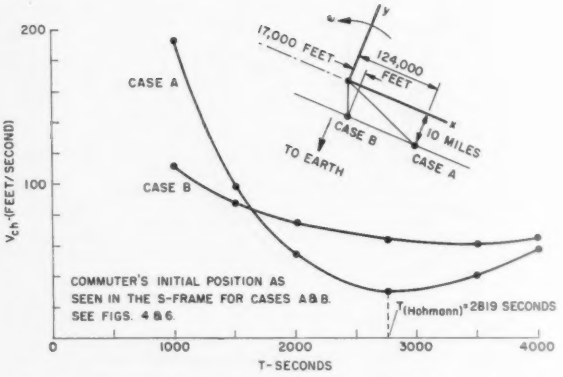
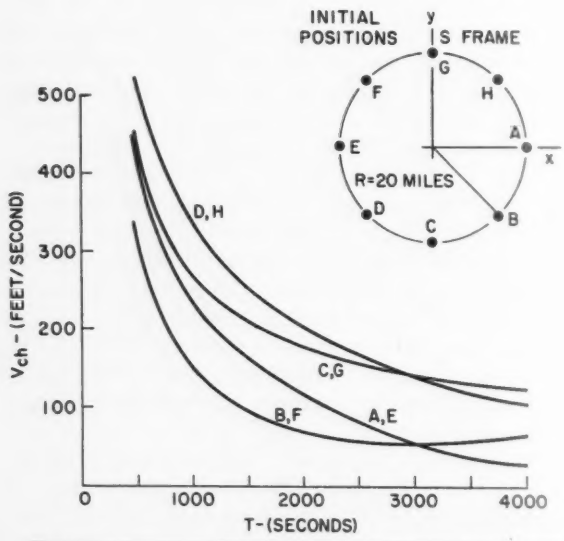


Fig. 8. Characteristic velocity vs. total time for rendezvous transfer from 290-mile altitude orbit to 300-mile orbit for initial conditions as shown. (See trajectories in Figs. 4–7.)



TOTAL TIME T, (SECONDS)	FIGURE	CHARACTERISTIC VELOCITY-fps CASE			
		A,E	B,F	C,G	D,H
500	10	440	340	450	522
1000	none	229	142	263	321
2000	11	103	73	186	201
3000	none	52	70	144	137
4000	12	27	86	135	109

Fig. 9. Effect of initial conditions and total time on the characteristic velocity

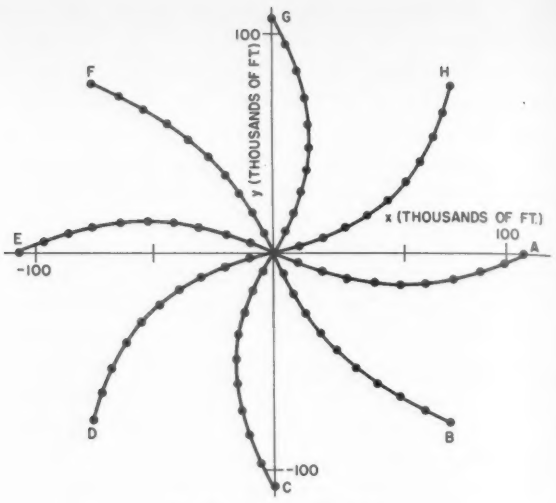


Fig. 10. S-frame trajectories.
(Total time is 500 sec. Points are at 50-sec. intervals.)

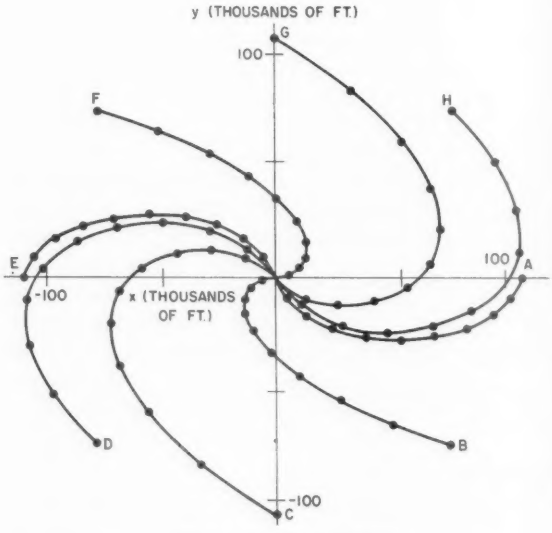


Fig. 11. S-frame trajectories.
(Total time is 2,000 sec. Points are at 200-sec. intervals.)

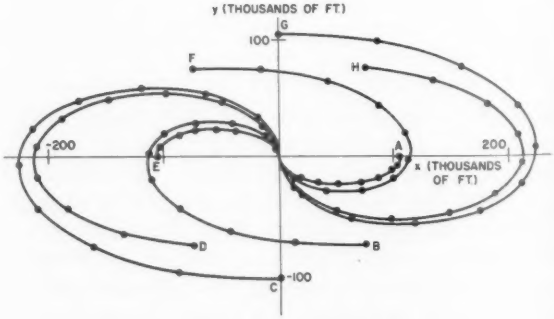


Fig. 12. S-frame trajectories.
(Total time is 4,000 sec. Points are at 400-sec. intervals. For comparison with Figs. 10 and 11 note different scale here.)

are 180° from each other. Also, note how the trajectories from a given initial position change with total time. These changes are most pronounced for cases C and G, directly above and below the satellite. However, the paths corresponding to cases A and E, directly in front of and behind the satellite, are quite near to each other for a wide range of the total time T.

The dependence of the required characteristic velocity upon initial position, as well as upon time, is shown in Fig. 9. From these curves it can be seen that the most desirable position for transfer times of less than half the orbital period (~2,850 sec.) is either below-and-behind or above-and-in-front-of the satellite. It will be recognized that the optimum position corresponds to the initial condition necessary for a Hohmann transfer.

Conclusions

Described here is a method of achieving rendezvous with a satellite which is in a circular orbit. Steering equations are given which express the desired velocity as a function of position and time. The resulting trajectory is essentially a coasting one, except for the initial and final impulses. However, this is not a true minimum-fuel rendezvous maneuver unless the initial conditions and the specified total time are those which correspond to a Hohmann transfer. In a recent paper,[5] Swanson, Petersen, and Hoover describe a method of achieving rendezvous by applying several impulses, all of which are parallel to the x-axis for the coplanar case. This yields a quasi-optimum rendezvous with respect to characteristic velocity.

In achieving rendezvous by these methods, however, a certain amount of fuel is required to change the established orbit of the commuter vehicle. Under ideal launch conditions, a saving in fuel would result from combining phases 3 and 4—that is, the thrust required to achieve orbital velocity would be varied according to information received from the tracking equipment aboard the commuter once lock-on has been established. This is sometimes referred to as *ascent rendezvous guidance*.

In this paper, we have assumed that the rendezvous maneuver is begun after the commuter has been placed into an orbit of its own. This has provided us with a basis from which to proceed in understanding the relative motion of the two orbiting bodies. The equations and the concepts used here can be extended to cover the more general noncircular, three-dimensional case and should be of practical use in satellite rendezvous missions, given initial conditions similar to those considered here. They might also be applied to the terminal phase of the return of spacecraft to their orbiting bases. In cases such as these, use of the S-frame provides a convenient reference system in which to observe and control the resulting relative motion.

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Catalytic Chemical Kinetic Theory

(Continued from page 31)

A review of these equations makes it apparent that in order to determine the optimum design to cover a range of reaction rates, reactor volumes, operating bed temperatures, feed rates, reactor pressure, concentrations, etc., a considerable number of calculations are required.

The computer design procedure should result in the optimum design for the desired reactor without experimental investigation. Before such a design is accepted as final, the validity of all assumptions made in the mathematical derivation of the basic equations must be checked experimentally. Any possible causes for limitations of the applicability of the kinetic rate equations should be carefully investigated.

When the packing materials are selected as catalysts for the given chemical reaction, then Eqs. (8) and (9) would not be valid. The reaction involved would now be a heterogeneous type, and the order of reaction would be influenced by the nature and extent of the catalyst surface.

Many of the scientific principles involved for heterogeneous catalytic reactions have been established. However, rigorous general theoretical treatment of many types of kinetic reactions is not, as yet, feasible and for engineering purposes the rates of such processes must be handled on an empirical basis.

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Helicopters and VTOL Aircraft

Criteria for Control and Response Characteristics in Hovering and Low-Speed Flight

"A study of the effects of various control power and angular velocity damping on pilots' opinions and ability to perform precision tasks during hovering and low speed."

Robert J. Tapscott, *Langley Research Center, NASA*

Mr. Tapscott received a Bachelor's degree in mechanical engineering in 1950 at the University of Virginia. Shortly thereafter he was employed as an Aeronautical Research Engineer at the Langley Research Center, NASA. He has been engaged primarily in flight research programs aimed at establishing criteria for flying qualities and stability and control of low-speed VTOL aircraft. Prior to studying engineering, Mr. Tapscott was on duty with the Army Air Corps and later the Air Force where he served as pilot of various categories of transport aircraft.

FOR SOME TIME the NASA has been using a variable response helicopter to study aircraft handling qualities at low speeds. Considerable emphasis has been placed on establishing basic criteria relating to characteristics which would provide satisfactory instrument flight capability in the hovering and low-speed range.

For most aircraft capable of hovering flight, the static stability parameters are generally such that oscillatory periods are fairly long and thus controllable. The lack of attitude stability as such in the hovering and very low-speed range tends to highlight the importance of the initial response characteristics when control inputs are made or when external disturbances are encountered. The more pertinent parameters in this case are the control power, that is, the angular acceleration of the aircraft in pitch, roll, or yaw obtained for a given control deflection, and the angular velocity damping, or restoring moment proportional to angular velocity.

References 1 and 2, in particular, have pointed out that large improvements in handling qualities at low speeds could be realized from increases in angular velocity damping. Reference 3 reports the effects on flying qualities, as determined in flight, of several combinations of control power and damping moment. This paper deals primarily with the application of those and other results as criteria for handling qualities in hovering and low-speed flight.

Test Results

Some detailed studies of control power and damping, which will be part of the basis of the criteria to be discussed, were made using a conventional single rotor helicopter (Sikorsky S-51). The control power and damping were varied with electronic components operating the conventional cyclic and tail-rotor pitch controls. The helicopter was instrumented to record angular velocities about all axes, airspeed, altitude heading, all pilot's control motions, and, in some cases, for instrument work, flight-path error. By performing precision tasks such as visual hovering and instrument approaches, as well as general flying, with various control power and damping values, time histories and pilot's comments were obtained. With the aid of a semi-statistical analysis of the flight records an evaluation of each condition was obtained. These results have been used to construct boundaries or zones showing the satisfactory combinations of control power and damping. Fig. 1 shows these boundaries for each of the three axes, roll, pitch, and yaw. The results are plotted

in terms of the ratios of control moment and damping moment to the moment of inertia about the appropriate axis. Thus, the abscissa values represent the angular acceleration or, relative to a time history of angular velocity, the initial slope of the angular velocity curve following a control displacement. Similarly, the ordinate values are a measure of the damping of the angular velocity response. The reciprocals of the numbers shown are the time, in seconds, that it takes for the angular velocity of the aircraft to reach about 63 per cent of the steady-state value resulting from a given control input. Outside the lower lines on each plot is the unacceptable region; the inner lines mark the desirable ranges. In this case the word "unacceptable" refers to conditions which are judged as inadequate even for visual operations, but not necessarily unflyable. The desirable ranges are intended to show those combinations which are judged good for instrument flight operations. It is of interest to note here the comparative responses found desirable for the different axes. The angular accelerations for the roll axis are about twice that in pitch. For the yaw axis almost an order of magnitude higher accelerations were found desirable. Similar magnitudes for the damping parameters are indicated and in each case, for the ranges tried, more damping moment gave increasingly more desirable characteristics.

Control and Response Criteria

The application of test results such as those presented in the previous section to the design of an aircraft requires some form of criteria which will account for different gross weights and moment-of-inertia characteristics and preferably which will take some account of the amount the aircraft is disturbed. With these test results as a general guide, but with considerable shading of some points by use of existing criteria, such as references 4 and 5, and from qualitative results of research pilot experience in other helicopter types of various sizes and configurations, including some of the current VTOL test-bed designs, general criteria have been formulated. These criteria are shown in equation form in Fig. 2. On the left are shown expressions for the damping moments about the respective axes as a function of the moments of inertia. Direct scaling of the

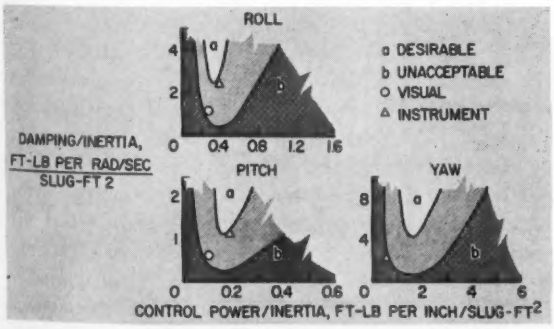

Fig. 1. Handling qualities boundaries as a function of control power and angular velocity damping.

	ANGULAR VELOCITY DAMPING FT-LB/RAD/SEC	ANGULAR DISPLACEMENT IN GIVEN TIME FOR ONE (1) INCH CONTROL DISPLACEMENT DEGREES	
	VISUAL		
PITCH	$8(I_Y)^{0.7}$	$45/\sqrt[3]{W+1,000}$	(1 SEC)
ROLL	$12(I_X)^{0.7}$	$27/\sqrt[3]{W+1,000}$	$(\frac{1}{2}$ SEC)
YAW	$27(I_Z)^{0.7}$	$110/\sqrt[3]{W+1,000}$	(1 SEC)
	INSTRUMENT		
PITCH	$15(I_Y)^{0.7}$	$73/\sqrt[3]{W+1,000}$	(1 SEC)
ROLL	$25(I_X)^{0.7}$	$32/\sqrt[3]{W+1,000}$	$(\frac{1}{2}$ SEC)
YAW	$27(I_Z)^{0.7}$	$110/\sqrt[3]{W+1,000}$	(1 SEC)

Fig. 2. Criteria for minimum acceptable control power and angular velocity damping.

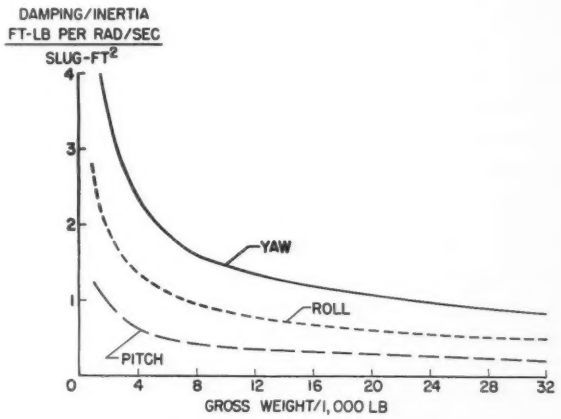

Fig. 3. Minimum angular velocity damping for visual flying.

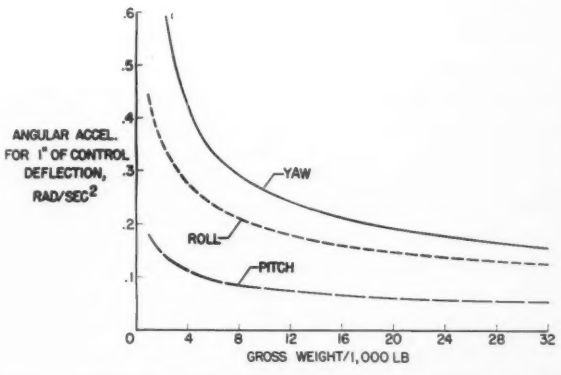

Fig. 4. Minimum angular acceleration capability for visual flying.

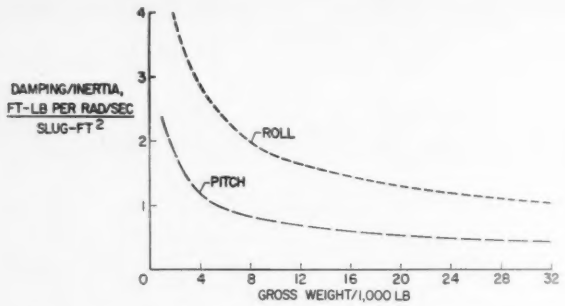

Fig. 5. Minimum angular velocity damping for instrument flight.

inertia values would indicate an exponent of 0.8 on the inertia for the damping expression. The seven-tenths (0.7) exponent shown is an empirical value and tends to make allowance for the fact that larger aircraft appear to require somewhat less damping than direct scaling of inertia would imply. On the right of Fig. 2 are shown expressions for the angular displacements of the aircraft in a given time following an abrupt 1-in. control input. For the pitch and yaw cases these expressions represent displacements reached at the end of 1 sec. About the roll axis, the displacement represented is at the end of 1/2 sec.

The control power criteria are presented here in terms of angular displacements in a given time rather than angular accelerations for several reasons. For a given damping, the angular displacements in a given time define the angular accelerations required; they provide a more measurable quantity for use as criteria and one directly appreciated by the pilot in correcting attitude deviations. In addition, in cases of very high or low values of damping at a given weight, proportionate variations of control power (angular acceleration) are obtained. Another less obvious result is that in many configurations the source of high damping moments also causes greater static stability (e.g., weathercock stability of tail rotor). Thus, in a rough sense, the disturbance tendencies are included in the criteria, by calling for greater control powers in configurations which are more subject to external disturbances.

Two sets of equations are shown in Fig. 2. The expressions under "visual" represent those characteristics which appear to be a minimum need for visual or contact flight. Similarly, the expressions under "instrument" represent the minimum needs for instrument flight. In the case of the yaw axis, no distinction has been made between criteria for visual and for instrument flight. Several reasons exist for this. First, under instrument conditions at low speeds, roll axis characteristics rather than directional appear to be of primary importance with respect to heading problems. Second, the values specified for the yaw axis may prove to be rather high for the visual case. The possible reasons for this will be discussed in more detail in a later section.

To demonstrate the handling qualities associated with the criteria of the handling-qualities boundaries presented in Fig. 1, the locations of the points representing both the visual and instrument criteria to be arrived at for the test helicopter are shown. These are the locations denoted by the circle (○) and the triangle (Δ), respectively. The location of these points relative to the boundary lines shows the extent to which additional test results and experience were used to establish the criteria. In the case of yaw test results, it is believed that high weathercock stability inherent in the test helicopter, coupled with marginal directional control available for trim, make the test results less generally applicable. In case of pitch, possible reasons are not as clear cut; however, the differences point out in both cases the need for additional studies of this type, to establish the effect of static stability parameters, the task to be performed, and possibly other factors, on the control power and damping requirements.

Illustration of Effect of Size on Criteria

The criteria presented in the previous section were functions of both gross weight and moments of inertia about the respective axis. Figs. 3 and 4 show the variation in size of the control power to inertia ratio or angular accelerations per inch control, and damping to inertia ratios specified by the criteria as minimum characteristics for visual flight. Figs. 5 and 6 show similar curves for the instrument flight criteria. To get the damping variation as an approximate function of weight, the moments of inertia and weight relationship of the Sikorsky S-51 (HO3S-1) configuration used in the tests discussed previously were scaled directly, and the damping values for each gross weight were calculated from the scaled moments of inertia.

These figures are shown primarily to illustrate the variation of angular acceleration and damping to inertia ratios with size for a given configuration. Different weight-moment-of-inertia relationships would

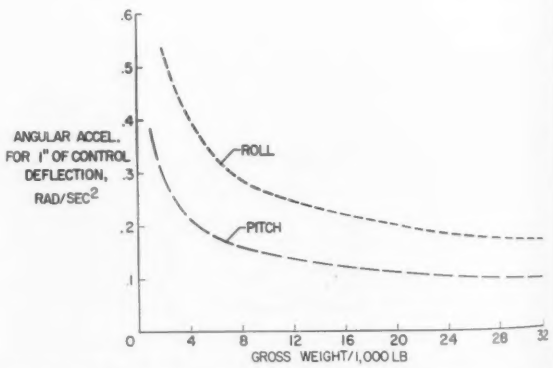

Fig. 6. Minimum angular acceleration capability for instrument flying.

show some difference in the values for a specified gross weight. Calculations show, however, that these effects are secondary, thus the curves of Figs. 3 to 6 also serve as useful guides in judging the control and response characteristics for any configuration of a given gross weight. Care should be used, however, in using the angular acceleration curves if the damping values present in the configuration being considered differ greatly from those shown on the damping curves for the given gross weight. In such a case, the displacements called for by the criteria in Fig. 2 should be used in conjunction with the actual damping values to determine an appropriate value for the angular acceleration.

Discussion

The criteria presented in the previous section have been found very useful in connection with NASA participation in the VTOL test-bed programs being conducted by the services. It has been used as a basis for suggesting control system changes both prior to initial flights and during flight test stages where control system modifications have been necessary.

The variable-response helicopter, in addition to its use as a research tool, has been found useful in simulating the VTOL test-bed responses in hovering flight. In this connection, the test helicopter has been used to familiarize both NASA and company pilots with the hovering characteristics of a particular configuration.

The applicability of the criteria which have been presented herein to the various configurations of the VTOL test beds is illustrated in Fig. 7. In this figure the control power and damping moment characteristics of several VTOL configurations are shown spotted on the handling-qualities boundaries determined from the helicopter tests. It is of interest to note that in each instance pilot's opinion regarding the configurations shown on the figure which have been flown have agreed substantially with what would be expected from the position of the points shown. For example, in the case of the tilt-wing roll axis (circles on Fig. 7) pilots report extreme care is needed to prevent catastrophic overcontrolling. In the case of the arrows representing the deflected jet VTOL (damping values for this configuration have not been established but are considered low since no stability augmentation is used), the pilot reports control power inadequate to control even very small disturbances. For the tilt-duct configuration, the points shown for pitch and yaw represent the approximate characteristics of the aircraft after several control system modifications to provide the needed control power. It is believed that the roll control power was increased by a considerable amount from the value shown before transitions were accomplished. The deflected slipstream configuration has undergone tethered tests and indications are that it will require increases in control power for satisfactory flight.

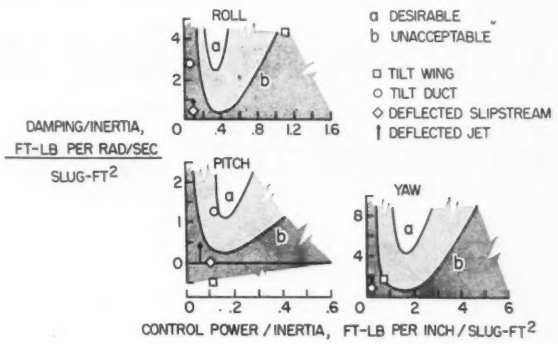

Fig. 7. VTOL configuration characteristics.

It is not intended to single out the configurations shown on Fig. 7 as being unique in having low values of control power and/or damping. It is desired to illustrate with these somewhat typical cases that all too often designers of new configurations seem to be much too hopeful of getting by with too little control power. In many cases the aircraft can be flown with these low values in what appears to be a satisfactory manner; however, these low values in conjunction with some lag in control system can lead to uncontrollable conditions. Also a problem in its own right which has not been discussed herein is that of control moments available for trim. Historically, aircraft designed for low-speed and hovering flight appear to end up with a deficiency about at least one axis in the control moments available for trim purposes.

In view of the fact that the tasks of hovering and landing are, in practice, precision maneuvers, the above considerations indicate that characteristics in this portion of the flight envelope should not be unduly compromised, even for aircraft designed for limited hovering time.

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Cryogenic Propellant Storage for Round Trips to Mars and Venus

Effective use of cryogenics for long-duration space missions requires that practical means be devised to prevent excessive propellant vaporization losses. It is shown that propellant losses can be minimized by using thermal radiation shielding and stage orientation with respect to the Sun. Parking time in low-altitude planet orbits was found to be the most important parameter controlling propellant heating.

George R. Smolak and Richard H. Knoll

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PRELIMINARY DESIGN of space vehicles for flights to other planets indicates that, for a given gross weight, large payload-weight advantages are possible by using high-specific-impulse rocket systems. This paper will be restricted to a discussion of the liquid chemical systems. Sloop[1] has shown that maximum chemical-rocket specific impulses are currently obtained with combinations of the liquid cryogenics—hydrogen and oxygen, for example.

Cryogenic propellants will become attractive only if they produce a substantial payload-weight advantage for a given gross weight compared with other chemical propellants. Unfortunately, many of the space-flight missions now being considered (one-way and round trips to Mars and Venus) require propellant storage for long periods of time (months and years). For such missions, there arises, then, the problem of reducing the vaporization loss of cryogenic liquids, due to heating, without requiring an excessive weight for thermal protection. It is this problem which we shall consider.

Features of Round-Trip Missions

Let us examine the features of a round-trip mission to Venus. A multistage vehicle begins its journey from a parking orbit around Earth. First, the vehicle escapes from Earth and coasts from Earth to Venus. Then, a parking orbit about Venus is established; the vehicle remains in this parking orbit while data-gathering and exploration are carried out. The return trip consists of escaping from Venus, coasting to Earth, and establishing a parking orbit about Earth.

Because of the large total-velocity increments required to carry out such round-trip missions, the potential payload advantage of an all-cryogenic vehicle over an all-storable vehicle ranges from about 500 to 1,500 per cent. Some of this advantage will certainly disappear when we take into account the amount of cryogenic propellant vaporized during the trip and the attendant weight of the thermal protection system. For such trips, each stage of the original multistage vehicle is subjected to different heating conditions and for much different periods of time. Since the terminal-stage propellants would be heated throughout the entire trip, it is likely that the potential payload advantage of the last stage would suffer the most. Thus, the prevention of excessive boiloff losses in a terminal stage is the problem that we shall discuss.

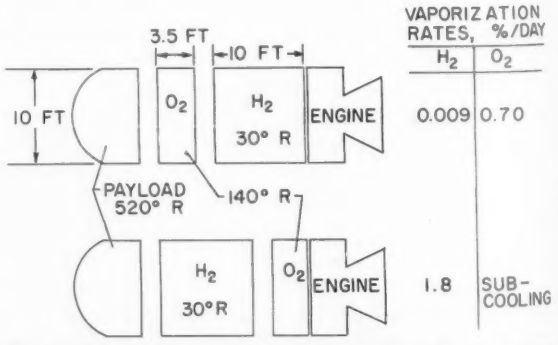

Fig. 1. Effect of component arrangement on propellant vaporization rates ($\alpha = \epsilon = 0.1$).

This article is a revised and condensed version of the authors' paper presented before the Space Propulsion Session, IAS 28th Annual Meeting, N.Y., Jan. 25–27, 1960.

After receiving his B.S. and M.S. degrees in mechanical engineering from the University of Michigan in 1950 and 1951, Mr. Smolak joined the research staff of the Lewis Laboratory of the NACA. His work at NACA (now NASA) has included research and publications in the fields of ram-jet and turbojet afterburner combustion, plug nozzle cooling, turbofan cycle analysis, and the analysis of cryogenic propellant storage problems. He is a registered professional engineer and a member of the ASME, ARS, and SAE.

Mr. Knoll received his B.S. degree in mechanical engineering from the Michigan College of Mining and Technology in 1957. Immediately upon graduation, he joined the Lewis Flight Propulsion Laboratory of the NACA and shortly thereafter was called into the USAF for a period of 28 months. He remained at Lewis during his tour of duty and rejoined the NASA (formerly NACA) upon discharge from the USAF. He has been associated with VTOL aircraft and aerodynamic boost heating problems, but has been primarily concerned with methods of storing cryogenic liquids in the environment of space.

Sources of Propellant Heating

In order to devise means of minimizing boiloff losses, a knowledge of the thermal environment of the cryogenic storage system is required. In general, heating of the propellants in space will be due to both internal and external heat sources. Internal heating results from radiation and conduction between adjacent components. The external sources of propellant heating are the Sun, the planets, and the galaxies. Heat is transferred from these sources to the propellant tanks by radiation.

The energy received from the Sun can be expressed in the form of a heat flux. This flux is inversely proportional to the square of the distance from the Sun and, at the Earth's distance from the Sun, is about 430 B.t.u./hr.ft.^{2}

The heat energy received from a planet is composed of thermal radiation from the planet due to its temperature and that portion of the Sun's heat energy which is reflected from the planet. At low altitudes, this planetary flux can be the same order of magnitude as the solar flux. For example, 100 statute miles above the sunlit Earth the planetary flux is equal to about one half of the solar flux.

The galactic heat flux, however, is extremely small. Ambartsumyan[2] estimates that it is about 1.8×10^{-5} B.t.u./hr.ft.^{2} These, then, are the various sources of heat with which we must contend.

Thermal Protection Methods

Internal Protection

With the sources of propellant heating defined, we can now examine several methods of thermally protecting the propellants. Consider first the internal heating problem. In Fig. 1, sketches of possible configurations of our terminal stage are shown. Thermally speaking, the stage consists of a fuel, an oxidizer, and a payload. For this example we have assumed that its slightly precooled propellants are hydrogen at 30°R. and oxygen at 140°R. and that its payload has a regulated temperature of 520°R. The engine is assumed to be at the same temperature as its adjacent component except for the brief propulsive periods. This figure demonstrates the effect of component arrangement on the propellant boiloff rates. These rates are due to internal heating—that is, this is a thermally isolated system with heat transfer only through the ends of the tanks. Later, we shall also consider the heat transfer through the tank sides.

To accentuate the vaporization problem, relatively small 10-ft.-dia. tanks were selected. Larger tanks would have resulted in lower vaporization losses. A stage of the proportions shown would weigh about 40,000 lbs., of which about 9,000 lbs. could be payload.

The vaporization rates for the two component arrangements shown indicate how serious internal heating can be. In the top arrangement with the components in descending order of temperature, the oxygen boiloff rate is relatively large—about 0.7 per cent per day. In other words, all the oxygen would boil away in less than 145 days. In the bottom arrangement, with the hydrogen surrounded by higher temperature components, all the hydrogen would vaporize in less than 57 days. With either arrangement, one of the propellants would be completely vaporized in a few months. However, the top configuration, having components in descending order of temperature, appears to be the better arrangement.

What can we do to lower these varporization rates? Inserting a heat barrier between components should help. We can use insulation or what we shall call multiple foils. Ideally, multiple foils are closely spaced, thermally isolated reflective surfaces. The theoretical heat transfer through these ideal foils is a function of

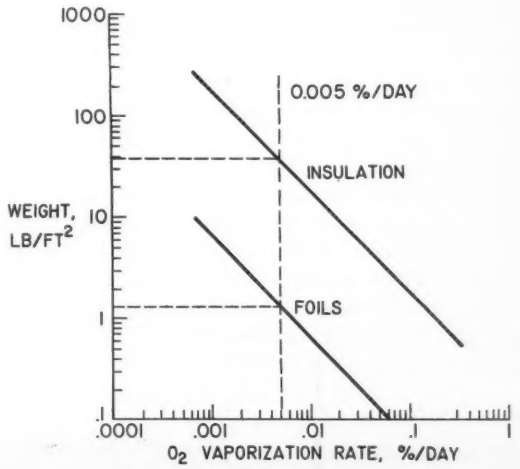

Fig. 2. Effectiveness of foils and insulation in reducing O_2 losses.

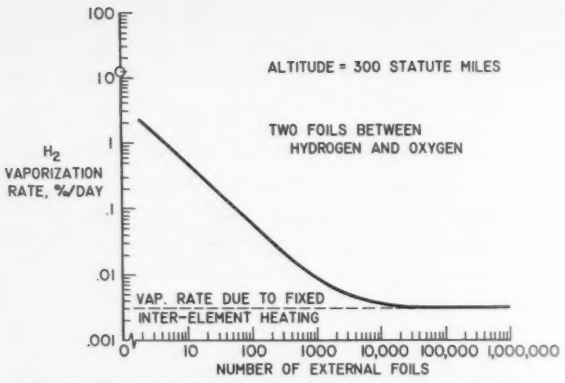

Fig. 3. Effect of number of external foils on H_2 vaporization rate ($\epsilon = \alpha = 0.1$).

their absorptivity and emissivity—low values yielding low heat-transfer rates. For the rest of this paper, we shall conservatively assume that absorptivity and emissivity are equal to one tenth. The resultant heat-transfer characteristics of these ideal foils (with absorptivity and emissivity equal to 0.1) are very close to those of several commercial products consisting essentially of alternate layers of foils and glass fiber paper.

How much insulation or how many foils do we need, and how do their weights compare? Because in the top configuration (Fig. 1) the oxygen boiloff problem is much worse than that of the hydrogen, let us consider inserting a thermal barrier between the payload and oxygen. Fig. 2 shows the weight in pounds per square foot of foils and insulation required behind the payload to produce various levels of oxygen vaporization rate in per cent per day. Here again, we have assumed that there is heat transfer only between components. The insulation material assumed is finely divided perlite, which has an extremely low thermal conductivity in a vacuum. For the full range of oxygen vaporization rates indicated, foil weights are less than one tenth of the insulation weights.

A boiloff rate of about 0.005 per cent per day might be considered acceptable here, inasmuch as the total oxygen loss for a 400-day Mars or Venus round trip would then be only 2 per cent. This loss rate could be achieved by employing a 150-foil material weighing only about 1 lb./ft.^{2} and occupying less than 4 in. of thickness.

From a similar analysis, it was found that only two foils would be required, between the hydrogen and oxygen tanks, to reduce the hydrogen vaporization rate to about 0.003 per cent per day.

For the rest of the paper it will be assumed that two foils are used between the hydrogen and oxygen tanks and 150 foils are used between the oxygen tank and the payload. These numbers have been selected merely to assist in the investigation of other parameters. The optimum number of interelement foils would depend upon the mission profile and the tank sizes.

External Protection

Next, let us consider the problem of boiloff losses due to heating from the external sources. First, we shall consider the effect of the nearly parallel rays of solar flux. By orienting the axis of our terminal stage parallel to these rays, the projected area exposed to solar flux is minimized. With direct solar radiation on one end of the hydrogen tank, the resultant hydrogen vaporization rate is enormous—11 per cent per day, in fact. We could reduce this rate by adding foils on this end of the tank. If we assume that a reasonable boiloff rate is on the order of 0.005 per cent per day, as we did for the internal heating, the foils required would weigh about 12 lbs./ft.^{2} This is rather heavy. The simplest method of avoiding the heating effect of solar radiation is to reverse the orientation of the stage and make use of other vehicle components for protection. With the payload pointed directly at the Sun, advantage can be taken of the protection offered by the high-temperature payload and the foils behind it. For this orientation, the hydrogen and oxygen vaporization rates are only about 0.003 and 0.002 per cent per day, respectively. These boiloff rates are due completely to heating from internal sources. The heating effect of the cryogenics by direct solar radiation has been eliminated by orientation.

We have just shown that, although solar flux was large, its heating of the propellants could easily be avoided. However, it is much more difficult to provide protection against planetary flux, which was stated earlier to be less than the solar flux. This is because, at low altitudes, the planetary flux will always be incident on the sides of the tanks, no matter what orientation of the stage with respect to the planet is used. We might just as well continue pointing the payload at the Sun and use a heat barrier on the tank surfaces exposed to planetary flux. Again, multiple foils are found to be the better material.

In Fig. 3 we can see how serious planetary heating can be when the stage operates at a low altitude, and also to what extent the use of foils can alleviate the problem. The hydrogen boiloff rate for a stage 300 statute miles above a fully sunlit Earth is shown versus the number of external foils. Without any foils to protect the tanks from the Earth's heat flux, the hydrogen boiloff rate is the exorbitant value of 13 per cent per day. Order-of-magnitude increases in the number of external foils produce order-of-magnitude decreases

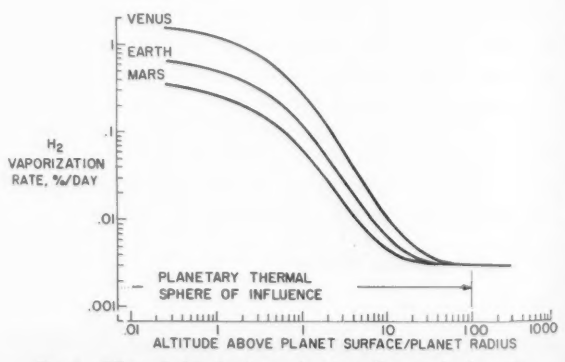

Fig. 4. Effect of altitude above planets on H_2 vaporization rate.

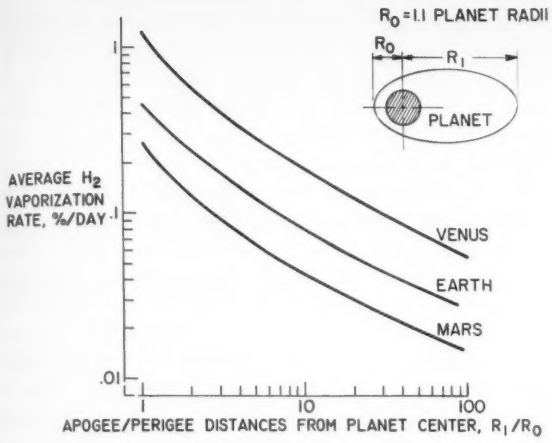

Fig. 5. Effect of elliptic orbits on H_2 vaporization rates.

in boiloff losses. For example, using two external foils gives a boiloff rate of about 2 per cent per day, and using 20 external foils results in boiloff rates of about 0.3 per cent per day. The vaporization rate for very large numbers of external foils approaches the rate due to internal heating—that is, 0.003 per cent per day.

At this point, as with internal heating, we really cannot say what an acceptable vaporization rate might be. Its value depends very strongly on the altitudes at which the stage will be required to operate and the length of time it will be at these altitudes.

Trajectory Considerations

Planetary Orbits

In Fig. 4 we can see the effect of altitude above Venus, Earth, and Mars on the vaporization rate of hydrogen. The protection system assumed utilizes solar orientation, the fixed number of foils between the elements of the stage, and ten external foils. We can see that the boiloff rates decrease rapidly as altitude increases and tend to level out at the very high altitudes. The "planetary thermal sphere of influence" for these stages extends to about 100 planet radii. At higher altitudes, planetary heating effects are negligible. For a given altitude, Venus, Earth, and Mars—in that order—go from high to low boiloff rates. Planet albedo, distance from the Sun and planet temperature produce this order of boiloff rates.

These rates given on the curve are equivalent to the rates that would be encountered in circular orbits. Thus, we can see that the boiloff losses for long-duration, low-altitude circular orbits would be prohibitive. If we want to reduce these losses, we must go to higher altitudes. However, mission requirements may call for low-altitude orbiting, possibly for observation or data-gathering. The total propellant vaporized in any orbit is the integral of the vaporization rate with respect to time. Therefore, decreasing the percentage of time at low altitudes will decrease the total boiloff losses. This can be accomplished by using elliptic orbits.

Fig. 5 shows the effect of elliptic orbits on the average hydrogen boiloff rates. The abscissa parameter characterizing the ellipse is the ratio of apogee-to-perigee distance—i.e., R_1/R_0 where R_0 equals 1.1 times the planet radius. Orbits from highly elliptic to circular have been shown for Venus, Earth, and Mars. An order-of-magnitude decrease in the circular orbit boiloff rates can be obtained by using highly elliptic orbits. At Venus, for example, the vaporization rate is about 1 per cent per day for a circular orbit, and only 0.1 per cent per day for an elliptic orbit with $R_1/R_0 = 20$. Thus, when we can use them, elliptic orbits are very beneficial.

Escape or Capture

Other boiloff losses, which are dependent upon the time-altitude history, are the losses incurred during the escape or capture phase of our missions. For either phase, the amount of propellant vaporized is influenced by the stage thrust-to-weight ratio. It is this parameter which controls the length of time spent at low altitudes.

For an initial circular orbit altitude of 1.1 times the radius of the Earth, the boiloff losses in reaching 100 Earth radii approach about 0.03 per cent at the high thrust-to-weight ratios. At lower thrust-to-weight ratios, the propellant vaporized increases rapidly because the time required to reach 100 radii increases rapidly. Since chemically powered space stages generally have thrust-to-weight ratios greater than about one tenth, it is concluded that vaporization losses during the escape and capture phases will be trivial.

Interplanetary Trajectories

For the solar orientation assumed, the interplanetary boiloff losses depend on the internal heating rates and the interplanetary trip times. Even though our stage has only a small amount of internal protection, the internal boiloff losses for typical Mars or Venus round trips are only about 1 per cent.

Payload-Weight Optimization

Now that we have considered boiloff losses for each phase of our round-trip missions, let us review briefly what we know. First, we saw that the major sources

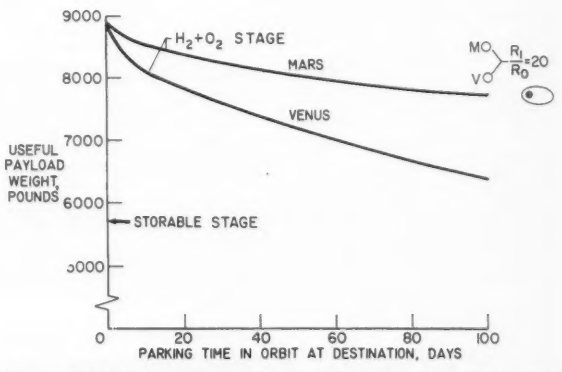

Fig. 6. Effect of planet parking time on useful payload weight for round trips.

of propellant heating were solar and planetary radiation and heat transfer between components. Solar heating was avoided by stage orientation. Internal heating was controlled by using foils between elements of the stage. Protection against planetary radiation was more difficult, but again could be provided with external foils. The amount of this external protection was found to depend strongly upon the type and duration of the parking orbits.

The important effect of parking time in orbit on the useful payload weight of a terminal stage for round trips to Mars and Venus is shown in Fig. 6. For each trip, the amount of foil material covering the tank surfaces exposed to planetary heating was varied in order to find that amount which would minimize the combined weight of the propellant vaporized and the heat-barrier material. This combined weight was subtracted from the nominal 9,000-lb. payload weight to get a useful payload weight for each mission. Total trip time for the missions shown varied from about 400 to 500 days. The parking orbits assumed are circular at 1.1 times the planet radius. For no parking time, the payload weight of the cryogenic stage is about 60 per cent greater than that of a storable hydrazine-nitrogen tetroxide stage. This storable stage was designed to have the same gross weight and to provide the same velocity increment as the hydrogen-oxygen stage. For a parking time of 100 days, this weight advantage reduces to about 35 per cent for the Mars round trip and to about 10 per cent for the Venus round trip.

As shown earlier, if mission requirements permit, large reductions in boiloff losses can be achieved by using elliptic orbits instead of circular orbits. The circles on the right show that, if the parking orbit is elliptic rather than circular, the payload-weight advantage of the cryogenic stage for 100 days' parking time can be improved to about 50 per cent for the Mars trip and 40 per cent for the Venus trip. These 100-day parking time trips are rather extreme cases. If we consider a more representative trip, say one with 20 days' parking time around Venus, the payload-weight advantage increases to about 50 per cent. In other words, the cryogenic stage would retain about 87 per cent of the original 9,000-lb. payload. This stage would require only about 3 in. of external foils on the hydrogen tank and only about 1/2 in. on the oxygen tank. It should be recalled that stages other than the last will suffer less from vaporization losses than the terminal stage, which we have considered in Fig. 6. For example, considering the specific Venus round trip with 20 days spent in a low-altitude circular orbit around Venus, the potential payload advantage for the complete multistage vehicle is about 500 per cent. When the vaporization losses of each stage and the attendant thermal protection system weights are taken into account, the overall payload advantage is still a very respectable 420 per cent.

Conclusions

An analysis was made to determine reasonable methods of achieving acceptable cryogenic boiloff losses for round trips to Mars and Venus. The internal and external sources of propellant heating were examined. Stage orientation and multiple-foil heat barriers were found to be effective thermal protection devices. Parking time in low-altitude planet orbits was found to be the most important parameter controlling propellant heating. The useful payload weight of a specific terminal stage was optimized for both Mars and Venus round trips. The payload weights were found to be substantially greater than those of a comparable storable stage. Thus, it is concluded that propellant heating need not be a serious limitation in the future use of cryogenics.

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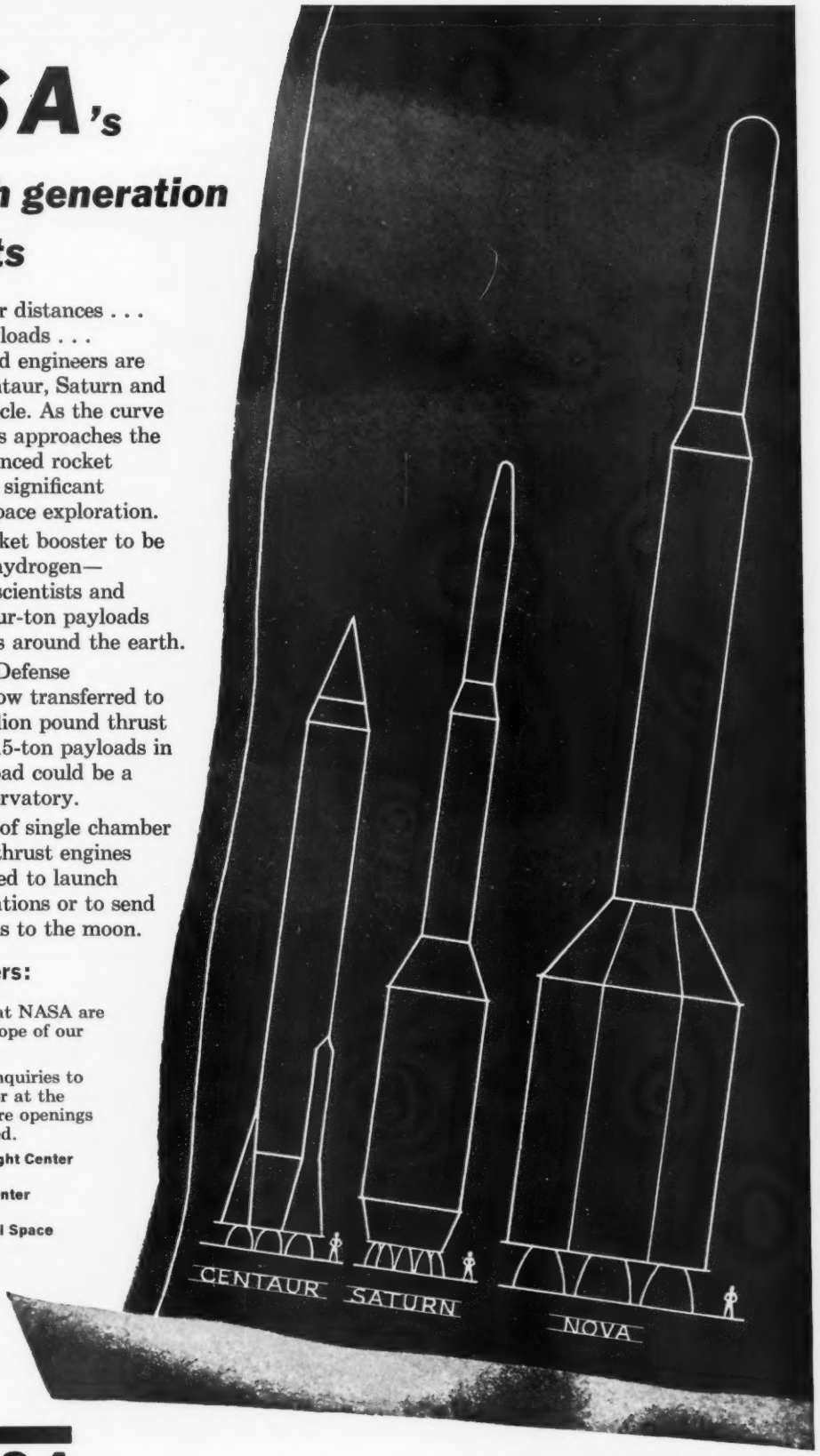

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form plastically, other than during creep, up to their melting point. Indeed, the strength (and, by implication, ductility) of oxides tends to decrease at elevated temperature as the fracture mode changes from cleavage to intergranular. However, some intermetallic compounds, which have metallic bonding, have a significant capacity for plastic deformation at elevated temperatures. Some data of Westbrook,[3] shown in Fig. 6, illustrate this point. It is apparent that even the most ductile of these (Cu_3P) has about the same transition temperature as the more brittle metals.

The low-temperature ductility of the refractory metals may be improved by increasing the purity. There should be no second phases to locate at the grain boundaries, particularly oxides with low contact angles at the grain boundaries. Further improvement in purity to reduce the content of soluble interstitial will improve the low-temperature ductility. These impurities increase the shear stress required to initiate movement of dislocations. Pinning of dislocations by interstitial atoms raises the flow stress progressively as the temperature decreases until the stress exceeds that required for fracture and brittleness occurs. A second general method for improving the low-temperature ductility of materials is to reduce grain size. The stress for propagation of cracks varies inversely with the square root of the grain diameter. Sometimes ductility may be improved by alloying. The addition of 50 per cent of rhenium to molybdenum and of 25 per cent rhenium to tungsten are cases in point. These alloys are solid solutions of the base metal, and are thought to be more ductile by alteration of the morphology and composition of the oxide to a nonwetting variety, reducing the interstitial solubility, and by promotion of twinning.

Purification and grain refinement are the major tools for improving low-temperature ductility. Unfortunately, many of the procedures for improving the purity also increase the grain size. It is usually necessary, even for high-purity materials, to reduce the grain size by mechanical working before maximum low-temperature ductility can be achieved. A further mechanism, which is important in refractory metals, occurs by working below the recrystallization temperature. The basis for the improvement is still somewhat obscure, but is thought to be a combination of rheotropic recovery, through breaking of interstitial atmospheres free of the dislocations, and preferential grain orientation. The ductility generally is better in the direction of grain flow than transverse.

(This article will be concluded in the July issue. Part II will discuss the high-temperature behavior of refractory materials.)

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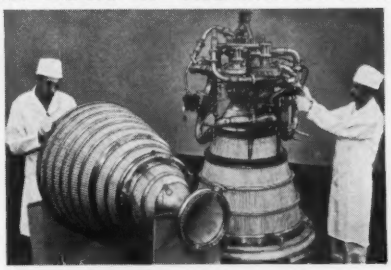

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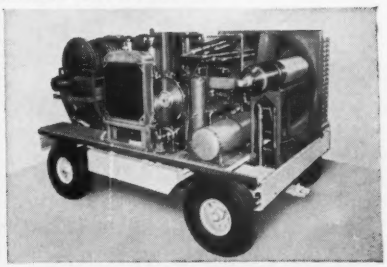

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S. E. Danyow (A) has been named Vice-President, Rocket and Ballistic Operations of Rocket Power-Talco Division of The Gabriel Co. He was formerly General Manager of the Talco Engineering Co., Mesa, Ariz., operations.

Robert G. Dreves (M), formerly Head of the U.S. Naval Training Device Center's Operational Flight Trainers Division, has been named to head the Center's newly formed Air and Space System Trainers Dept.

William H. Enders (M) has been named Manager, Market Research and Analysis, Missile Electronics & Controls Division, Defense Electronic Products, Radio Corp. of America. Mr. Enders was previously Group Leader, Air Defense Studies, with RCA's Airborne Systems Lab.

Kenneth M. Foreman (A), formerly Principal Scientific Research Engineer assigned to the Plasma Propulsion Project of Republic Aviation Corp., has been named Specialist, Scientific Research Engineer, with the same organization.

C. Towner French (A) has been appointed Manager of the Washington, D.C., office of GPL Division, General Precision, Inc. Mr. French was formerly in charge of GPL sales planning activities.

J. H. Friedman (A) has been appointed Production Design Engineer, Transport Aircraft Engineering Dept. of Douglas Aircraft Co. Prior to his new position, Mr. Friedman has been on a 6-month special assignment in Missiles Engineering.

Dimitrius Gerdan (AF), former Director of Engineering, Allison Aircraft Engines Operations, has been appointed Manager, Aircraft Engines Operations, Allison Division of General Motors.

A. H. C. Greenwood (M) has been appointed an additional Director of Vickers-Armstrongs (Aircraft) Ltd. He has been Deputy General Manager at Weybridge since 1958 and a special Director of the company since 1955.

Geza S. Gedeon (M) has been appointed Head and Research Scientist of the Astrodynamics Laboratory of Astro Systems and Research Laboratories, Norair Division, Northrop Corp. Prior to joining Northrop, Dr. Gedeon was Senior Scientist at Ford Motor's Aeronutronic Division.

Ernest J. Greenwood (AF), formerly Manager of United Aircraft Corp., Norden Division's Milford department, has been named Operations Manager for Norden's Norwalk facility, now under construction.

George E. Grega (M) has been named Manager of G-E's Flight Propulsion Division (Central District). He was formerly Manager, Operation Planning, for the Division's Evendale, Ohio, plant.

William H. Klenke, Jr. (AF), *third from left*, was recently promoted to the rank of Brigadier General in the U.S. Marine Corps Reserve. General Klenke, a sales executive with Chrysler Corp., is senior Marine Reserve officer in Michigan. Inspecting a 1919 "Jenny" two-place trainer at the Greenfield Museum in Dearborn are, *from left*, Lt. Gen. Karl S. Day, USMCR (Ret.); Brig. Gen. Harry Van Lieu, USMCR; and Brig. Gen. Frederick E. Leek, USMC.

Marshall C. Harrington (M) has been named Contract Research Administrator at the Navy's David Taylor Model Basin in Maryland. Dr. Harrington was formerly Head of the Fluid Dynamics Branch at the Taylor Model Basin.

Delbert W. Jones, Jr. (M), has been named Southwest District Manager for G-E's Light Military Electronics Dept. He was formerly a product planner for the department in Utica, N.Y.

Lt. Comdr. Albert J. Kelley, USN (M), has been designated as Agena Vehicle Program Manager in NASA. He was previously assigned in the Navy Bureau of Weapons as Eagle Weapon System Project Officer.

James E. Knott (M) has been appointed Director of Engineering for Aircraft Engines Operations of the Allison Division of General Motors. Mr. Knott was formerly Assistant Director of Engineering.

David S. Lewis (AF), a Vice-President of McDonnell Aircraft Corp., has been named Senior Vice-President—Operations at McDonnell.

Robert C. Little (M), formerly Chief Test Pilot for McDonnell Aircraft Corp., has been named Assistant Manager, Customer Service, for the company.

Frank MacTernan (AF) has been appointed to the newly created position of Corporate Director, Airline Support Services, The Garrett Corp. Prior to joining Garrett, Mr. MacTernan was Assistant Representative in charge of West Coast offices for United Aircraft's Hamilton-Standard Division.

E. Gilbert Mason (M) has joined with associates in the purchase of Teco, Inc., designers and builders of aircraft seating systems. Mr. Mason will serve as President and General Manager of the company and will also be a member of the board of directors.

Lewis C. McCarty, Jr. (AF), has been named Director of Foreign Service for McDonnell Aircraft Co. Mr. McCarty was previously a contractor and consultant with The Martin Co.

J. H. Overholser (M), formerly Sales and Engineering Vice-President and Director of Poly Industries, Inc., is President of Dyna-Matics Corp. The company was recently formed by Mr. Overholser and an associate, E. H. Haag, for the manufacture of control equipment, valves, regulators, turbine flow meters, and pumps for aircraft, missiles, and ground support systems.

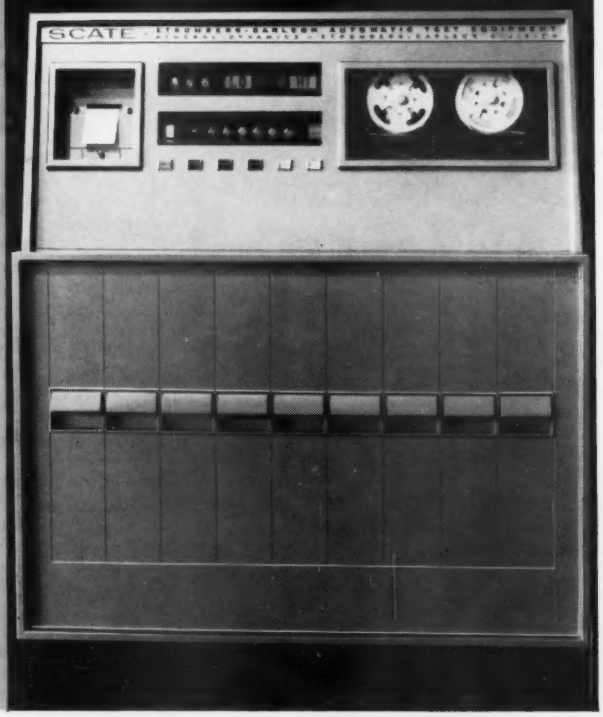
Thracy Petrides (M) has been appointed Director of Government Programs of U.S. Industries, Inc. Mr. Petrides was previously Head of USI's Military Systems Planning Group.

S. Ramamritham (M), formerly Deputy Director of Research and Development, has been named Director of Research and Development in the Civil Aviation Directorate of the Government of India.

Rear Adm. William T. Rassieur, USN (Ret.) (AF), formerly Corporate Military Adviser of Lockheed Aircraft Corp., has been elected President of The Hafnor Research Corp.

Dean C. Reemsnyder (M) has been

A TALENT FOR WEAPONS TEST EQUIPMENT



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assigned as Project Engineer in the Engineering Dept. of New Devices Labs., Thompson Ramo Wooldridge Inc. He was previously assisting in the analysis and design of nuclear auxiliary power units.

James W. Salassi (A) has been named Director of Marketing for B. H. Hadley, Inc. He was the company's sales representative in the southern and midwestern United States.

David I. Shapiro (A) has been appointed to the Customer Relations Staff of the Missile Products Division, Fruehauf Trailer Co. Mr. Shapiro was formerly Western Representative for Vertol Aircraft Corp. and Allied Research Associates.

John A. Stern (M) has been named European Factory Representative for United Air Lines, stationed at the Sud Aviation aircraft plant in Toulouse, France. Mr. Stern was formerly New Aircraft Coordinator at United's San Francisco maintenance base.

George Trimble, Jr. (AF), has been named Corporate Vice-President for Advanced Programs of The Martin Co. Prior to his new appointment, Mr. Trimble had been Corporate Vice-President of Engineering and General Manager of Martin's Space Flight Division.

Frederick C. Waite (M) has been named to head the newly formed Technical Support Dept. at the U.S. Naval Training Device Center. Mr. Waite was formerly Head of the Center's Production Dept.

William W. Wood, Jr. (M), formerly Vice-President—Simulator Engineering and Manufacturing, Link Division of General Precision, Inc., has been elected a Director of the corporation and Executive Vice-President of the Link Division.

Theodore P. Wright (HF), Vice-President of Cornell University in charge of the administration of sponsored research, will retire July 1. On retirement, Dr. Wright will continue as a trustee of the Power Reactor Development Corp. and a member of its Safety Committee, and as a consultant to the Reaction Motors Division of Thiokol Chemical.

Hsuan Yeh (M), Professor of Mechanical Engineering at the University of Pennsylvania, has been appointed Director of the University's new Towne School of Civil and Mechanical Engineering.

Corporate Member News

• **Allied Research Associates, Inc.,** has reorganized its technical efforts into two major divisions—Research and Engineering. The company recently became a wholly owned subsidiary of Boeing Airplane Co.

• **Avien, Inc.,** has announced that agreement has been reached for the acquisition of Colvin Laboratories, Inc., and Pressure Elements, Inc. Both firms will continue under the same management. In a later statement, Avien announced the formation of Trident Corp. as a subsidiary of Avien. The new company will carry out R&D in undersea technology.

• **Kollsman Instrument Corp.** has acquired Richardson-Allen Corp., manufacturer of industrial electrical equipment. The new acquisition will operate under its present name as a wholly owned subsidiary of Kollsman.

• **C. W. Lemmerman, Inc.,** of Hartford, Conn., has opened a branch office in the First National Bank Building, Miami, Fla.

• **Radio Corporation of America** has dedicated its new West Coast Electronics Center in Van Nuys, Calif. The plant consists of six large buildings for the engineering and production of missile checkout, guidance, control, and data processing and display systems.

• **Simmonds Aerocessories, Inc.,** has changed its name to Simmonds Precision Products, Inc.

• **Thompson Ramo Wooldridge Inc.** has concluded an agreement to acquire a controlling interest in Good-All Electric Manufacturing Co., manufacturer of electronic components.

IAS Sections

Chicago Section

McKay Professor on Gas Dynamics

Dr. Howard W. Emmons, Gordon McKay Professor of Mechanical Engineering at Harvard University, addressed the March 9 dinner meeting held in conjunction with the Mechanics Colloquium of Illinois Institute of Technology. The subject of Dr. Emmons' talk was "**High-Temperature Gas Dynamics.**" He described an experiment for verifying Poiseuille's law for high-temperature plasma flow.

Considerations leading to the design of the experimental equipment were discussed: heat resistant walls with low electrical conductivity; a suitable ionizing gas; arc initiation and control; temperature, pressure, voltage, and velocity measurement techniques; and associated cooling apparatus. He also developed the theory underlying high-temperature plasma flow taking into consideration internal gas reactions, ionization, and radiation. The experimental program remains to be carried out before verification of the theory can be made.

J. S. ISLINGER, *Chairman*

Indianapolis Section

V/STOL Research Aircraft

Arthur L. Williams, Project Engineer of Fairchild Aircraft and Missile Division, appeared before the March 16 dinner meeting. Mr. Williams discussed "**Fairchild M-224 VTOL Test Vehicle,**" covering current activity in the development of

Meet the Staff

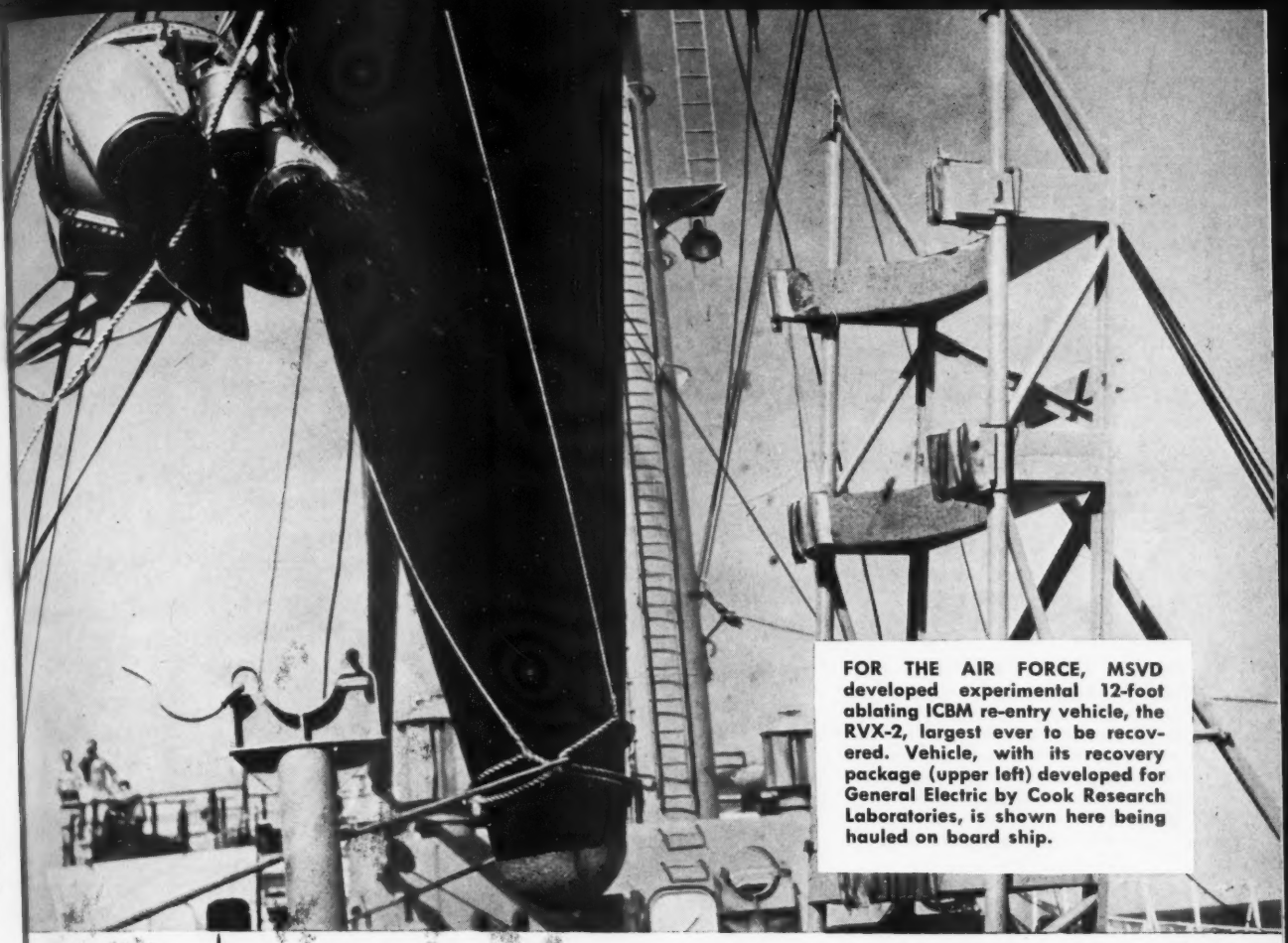
Nell Steinmetz—Our PAL

Mrs. Nell Steinmetz, Librarian, joined the Pacific Aeronautical Library in October, 1944, when it served six companies and had a circulation of 8,825 items. Today she supervises PAL, which serves 70-odd companies, with a 1959 circulation of 44,500 items.

PAL, a division of the IAS operating at the Institute's Western headquarters at 7660 Beverly Boulevard in Los Angeles, provides to subscribing companies cards, books, periodicals, check lists, and related materials for company librarians.

In addition to holding semimonthly meetings with librarians from subscribing plants, Mrs. Steinmetz is responsible for keeping in touch with ever-changing library techniques. She is a member of the Special Libraries Association (of which she was a Director for 3 years) and the American Documentation Institute (on whose Council she served for 3 years).

A Californian since age six, Mrs. Steinmetz has ventured to such far-flung places as Europe, North Africa, the West Indies, Bermuda, and Yucatan. She is a grandmother, with interests ranging from house-and-garden to mystery stories, concerts, and a pair of Siamese cats. K.B.



FOR THE AIR FORCE, MSVD developed experimental 12-foot ablating ICBM re-entry vehicle, the RVX-2, largest ever to be recovered. Vehicle, with its recovery package (upper left) developed for General Electric by Cook Research Laboratories, is shown here being hauled on board ship.

MISSILE AND SPACE VEHICLE DEPARTMENT

...center for missile and space technology research and development at General Electric

Progress in search and recovery

With each recovery of a space vehicle, scientists gain important new knowledge about the environment of space and its potential effect on man and the operation of vehicles and equipment. As more advanced vehicles are developed for space flight—some with life aboard—successful location and recovery become increasingly vital.

General Electric's Missile and Space Vehicle Department pioneered in the development of space vehicle search and recovery techniques as part of its re-entry and recovery vehicle program for the U.S. Air Force. MSVD developed and built the first payload to be recovered from space—an 18-inch data capsule ejected from an Air Force Thor re-entry vehicle on June 13, 1958. Many such data capsules have since been recovered from both Thor and Atlas flights—some carried cameras providing films from space. MSVD also developed and built the 12-foot long, one-ton re-entry vehicle shown above which the Air Force recovered on July 21, 1959—the largest to be returned to date. Today, as MSVD builds and flight tests more complex vehicles, it is continually expanding and improving its already successful search and recovery program.

Currently, this search and recovery experience is being applied to the development of such important space programs as the Air Force "Discoverer" recovery satellites and NASA's radiation research recovery vehicles (NERV).

For more information about MSVD's work in search and recovery, write to Section 160–79, General Electric Co., Missile and Space Vehicle Department, Philadelphia 4, Penna.

GENERAL ELECTRIC

MISSILE AND SPACE VEHICLE DEPARTMENT

A Department of the Defense Electronics Division

Scientists and Engineers interested in career opportunities in Space Technology, contact Mr. T. H. Sebring, Dept. 160, MSVD

MARQUARDT PAT-C* SYSTEM MAKES POSSIBLE PRECISION SPACE CONTROL

New control gives 3500 to 1 modulation and .001 pound-seconds impulse

Orbit correction, station keeping and attitude control of a 24-hour surveillance satellite which must orbit in a fixed position 24,000 miles above a predetermined point on earth, is but one unique application of PAT-C—position, attitude, trajectory control system—a development of The Marquardt Corporation's Controls and Accessories Division.

The PAT System is a highly responsive jet reaction control which controls the flight path, the position and attitude of a space vehicle as a result of intelligence inputs from the vehicle guidance system or ground control. The system is capable of providing the necessary corrective action based on simple positions and velocity air signals or will respond to the demand of complex guidance computers in the system. The thrust level can be adjusted over a range of 3500 to one (or more in some cases) with the same set of rocket nozzles; proportional control of thrust from 0 to full thrust is possible. Impulse imparted to the vehicle can be controlled accurately over a wide range down to a few milliseconds in duration—with a one lb. thrust nozzle as low as 0.001 pound-seconds. In the attitude control mode, the PAT system can maintain pointing accuracies not possible with other systems due to its low propellant consumption in limit cycle operation.

In a typical case, an accuracy of 0.1 seconds of arc can be held for 1000 hours with 40 lbs. of propellant.

Marquardt's fifteen years of research, development and production has resulted in state-of-art advancements in a wide range of electronic, electro-mechanical, pneumatic and hydraulic controls and accessories. For example, a pneumatic servo actuator is now available for 1600°F service—and severe nuclear radiation environments.

For additional information concerning the PAT-C System or other C & A capabilities, contact Dick Oblinger, Chief Applications Engineer-Controls and Accessories, The Marquardt Corporation.

Engineers and Scientists experienced in these or related fields will find it rewarding to discuss their career futures with Marquardt. Founded in 1944, Marquardt now has a staff of 5,000—two out of three are professional people. The company's growth is a parallel to the atmosphere of challenge and rewarding accomplishment that has existed since the firm's beginning.

Shown in photograph below—Marquardt engineers discuss a full scale mock-up of a complete self-contained PAT-C unit designed for application to space vehicles.

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*POSITION—ATTITUDE—TRAJECTORY CONTROL SYSTEM

V/STOL research aircraft. He indicated requirements for VTOL aircraft and described some of the current applications.

ROBERT SAFF
Publicity Chairman

Los Angeles Section

Aeroelasticity to Aerospace

G. L. Hobby, of California Institute of Technology's Jet Propulsion Lab., presented **"Closed Ecological Systems for Space Vehicles"** before the March 22 Specialists Meeting. Mr. Hobby reviewed the basic organic and energy cycles involved, and described the capabilities of photosynthetically active, green algae in handling the human metabolic requirements for most space missions.

▶ The March 8 Specialists Meeting presented **Prof. Y. C. Fung** of California Institute of Technology speaking on **"Panel Flutter—A Review of Research Progress."** Professor Fung gave the results of a survey made for the AGARD *Manual on Aeroelasticity*. He emphasized the paradoxes encountered in various theoretical studies. Experimental results for models built to simulate the approximate mathematical model were discussed. Movies of NASA tests on X-15 panels were also presented. A lively discussion of the topic followed the presentation.

S. J. COLBY
Secretary

Niagara Frontier Section

Genealogy of the Delta Wing

A. Burstein, Assistant Chief Engineer, R&D, Convair (San Diego) Div. of General Dynamics Corp., addressed the March 9 meeting. Mr. Burstein opened his discussion of **"The Delta Wing Story"** with the 1945 Air Force competition for a Mach 2.0 interceptor with a rocket/ram-jet propulsion system for which Convair successfully proposed the delta wing X-F92. At this time, three outstanding advantages of the delta wing became evident: (1) delay and reduction of the drag rise, (2) improved weight and thickness characteristics, and (3) simplicity. Mr. Burstein traced the genealogy of the delta wing from here through the Sea Dart, the Pogo, and the F-102 to the F-106 and B-58. During the course of the discussion he showed how area ruling and conical camber improved the drag on the F-102. He also discussed some aspects of engine inlets and flow straighteners, such as wing fences and notches as applied to the delta wing family.

For future applications, Mr. Burstein foresees a supersonic transport of a canard-delta configuration with 360,000 lbs. gross weight and 3,500 nautical miles range. He also predicts the application of delta wings to space re-entry vehicles. The talk was illustrated by slides and movies.

J. M. CORD
Secretary

Col. H. E. Watkins (M), Deputy Director of Materiel Headquarters SAC and Advisory Board member of the IAS Omaha Section, congratulates Cadet Taylor after presenting him with the Certificate of Merit at the section's March 11 technical paper competition.

Omaha Section

Technical Paper Competition, DynaSoar Project Manager Featured

Cadet William W. Taylor, Corpus Christi, Tex., presented the winning paper at a technical paper competition for cadets of the Air Force Academy sponsored by this section of the IAS. Cadet Taylor is a member of the Academy's IAS Student Branch. Competition was held at Offutt AFB on March 11, 1960.

The paper, **"A Method of Mid-Course Interplanetary Guidance,"** outlined a method of providing vehicle velocity in free space. Knowledge of vehicle velocity during the mid-course phase of space flight allows corrections to be made resulting in greater accuracy and less dependence on the terminal guidance system. Cadet Taylor's method is based on doppler shift. Two velocity vectors are obtained—a radial velocity vector from the sun and a tangential velocity vector from a planet. The sum of these two vectors results, after operation by a suitable computer, in vehicle velocity during mid-course.

▶ The February 18 luncheon meeting presented **George Stoner,** Project Manager, DynaSoar, Boeing Airplane Co. Mr. Stoner discussed **"The Effect of Innovation on the Next Decade of the Space Age."**

In developing his theme, Mr. Stoner used the airplane as an analogy. He reviewed the historical manner by which innovation has succeeded in justifying the confidence which early planners placed in the airplane. The most memorable of the airplane prophets was Gen. Billy Mitchell who had faith in the innovations that would make the airplane take its place in the national scene as we know it today. General Mitchell made his predictions in 1925 when the airplane was a very crude vehicle by today's standards.

Mr. Stoner stated that he had been unable to find evidence that General Mitchell anticipated in any exact form developments such as the jet engine, breaking the sound barrier, or the tremendous advances in rocket propulsion. All of these developments have had a great effect on the predictions he made, but it was not necessary for General Mitchell to predict these new developments in order to approximate the significance of the coming Air Age.

Predictions which General White, and other military strategists, make today regarding the importance of aerospace and pure space flight activity are not fundamentally based upon a particular design of a military spacecraft foreseen 10 years from now, any more than General Mitchell's predictions were based on a specific design of a particular airplane. Their predictions of importance are based upon fundamental principles. A few of these fundamental principles are the natural vantage point of space, a new freedom in communication and a fundamental to space flight, an indefinite duration of flight when required for continuous alert.

To the application of any of the aforementioned fundamentals can be foreseen the long and difficult tasks of designing, developing, and testing. Mechanism inventions and perfections by the hundreds will assist in achieving this kind of design effort. However, Mr. Stoner contends, the most important innovations, which will affect the ability of space machines, are not today directly related by the laboratory experimenters in the appropriate field to any military application of space flight. Just as the most tremendous increases in the might of air power came from radar and atomic energy work (unrelated in their initial form to aircraft), so will the tremendous steps forward in the exploration of space come tomorrow from laboratory activities today.

There is a great deal of experimentation under way today in the field of plasma propulsion. Mr. Stoner suggested that all of these experimenters may discover a greater utility to a knowledge of magneto-thermodynamics than any of the specific applications which today guide their work, especially when they combine the theoretical possibilities with continuously sustained flight through the vacuum of space.

There are many other areas which will have a significant influence on the full development of the space age. Further advances in the art of miniaturization of electronic equipment are necessary for space flight. During the past 10 years the development of transistor printed circuit and the concept of module packaging have introduced a new area in circuit miniaturization. Densities of 300,000 components per cu.ft. are now realized, resulting in an increase in component densities of greater than 10 to 1 over previous techniques.

The main point that Mr. Stoner made was that there are many areas of research taking place today, from business to long-hair scientific, which can have an impact on the utility of space flight. We may anticipate that some inventor will make unique combinations of these laboratory activities in a way which influences the

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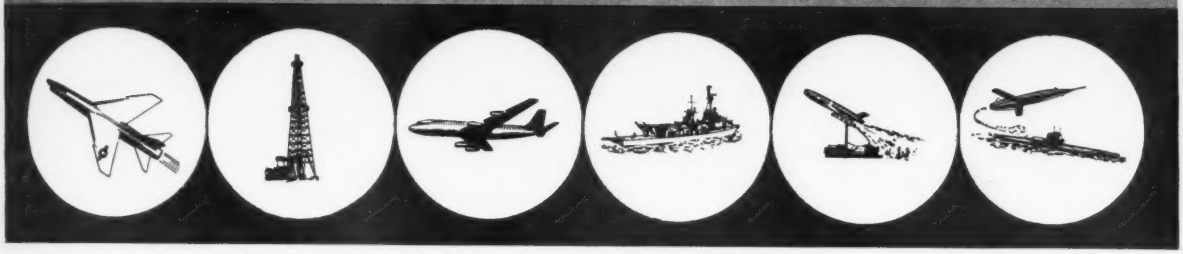

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– U.S. Supreme Court

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MICHAEL J. MCALISTER, *Secretary*

San Antonio Section

Air Logistics; San Antonio Science Fair

The importance of supplying worldwide support of Air Force activities by air instead of stockpiling critical material in overseas depots was highlighted by **Major Gen. Lewis L. Mundell,** Commander, San Antonio Air Material Area, Kelly AFB, in an address before the March 29 meeting. General Mundell pointed out that the military definition of logistics is "that part of a military activity that provides for the build-up and support of a military force by providing for supplies, equipment, transportation, maintenance, construction and operation of facilities, movement and evacuation of personnel, and other like services so as to render the military force efficient and effective in both combat and noncombat operations." Confining his remarks to the supplies and transportation, General Mundell commented that the speed of moving supplies to troops during the American Revolution was about $1^1/_2$ m.p.h. With high-speed electronic data equipment, new control procedures, and air transport, the speed has increased tremendously. He observed that, while visiting in Japan last fall, "using activities" had received items from Kelly in as little as 4 days after the activity had submitted the requisition, which was unusually fast. The average time required was 7 days. To give an idea of the amount of supplies being handled by the Air Freight Terminal at Kelly AFB, General Mundell mentioned that in 1959 more than 41,000 tons of material was processed in and out of the terminal by air shipment.

General Mundell closed his remarks by recognizing that the mechanization of freight handling, electronic data equipment, and high-speed transportation have not reduced the requirement for intelligent and dedicated personnel and paid tribute to the civilian and military personnel responsible for timely support of Air Force activities worldwide.

▶ The February 29 dinner meeting was addressed by **Theodore M. Szydowski, S.M.,** a member of the Mathematics Dept. of St. Mary's University, discussing **"Science Fairs—The Teeners' Triumphs."** He focused his presentation on the Alamo District Science Fair, held annually since 1957 in San Antonio.

Students whose exhibits are judged best are sent to the National Science Fair as entrants. Other awards are given by the Science Fair Committee, some donated by interested professional groups. The San Antonio Section of the IAS awarded a trophy to the best aeronautical exhibit.

This award, the General McMullen Trophy, was won by James Callaway, a senior at Alamo Heights High School, at the fair held April 2 and 3. The subject of his exhibit was boundary-layer control, consisting of a model airfoil instrumented with manometers and complete with home-built wind tunnel powered by an evaporative cooler. Mr. Callaway also was winner of the District Grand Prize of an all-expense-paid trip to the National Science Fair.

ROBERT C. COWAN, *Secretary*

San Diego Section

Field Trip; Space/Science Lecture Series

On March 12 a joint field trip was made, with the American Ordnance Association, aboard the Navy's missile test-bed ship, the U.S.S. "Norton Sound" (AVM-1). Guided tours of the ship, explained by officers in charge, included all of the specially installed missile test equipment. Of special interest was the nerve center of the ship, CIC (Combat Information Center), which housed the ship's missile radar scopes, tracking boards, communications and navigation equipment, the bridge, missile block house, data recording center, and missile maintenance and checkout shops. The "Norton Sound" is assigned to test all experimental Navy missiles and was used in Project ARGUS last September involving explosion of atomic warheads in space.

▶ The Section presented several sessions of its space/science lecture series in February and March. **Dr. Alan Schoen,** Physicist and Staff Scientist at Convair Scientific Research Lab., addressed the March 10 meeting. Speaking on **"Atom Movements in Solids,"** Dr. Schoen discussed the various ways in which atoms move in crystalline solids and how these motions influence the behavior of these solids. He also explained the mechanism for diffusion radiation effects and plastic deformations.

▶ **Dr. Melvin Cutler,** Senior Physicist at General Atomics, presented **"Solid-State Physics and Implications in New Devices"** before the March 15 meeting. Dr. Cutler discussed the general historical background of solid-state physics and outlined thermoelectric devices and tunnel diodes and discussed some of the special techniques required to manufacture these devices satisfactorily.

▶ The March 1 space/science lecture was presented by **Frederick A. Ford,** Chief of Preliminary Design for Convair-Astronautics. In his discussion, **"Vehicles for Interplanetary Flight,"** Mr. Ford described the current role of the Atlas in various space projects, emphasizing the "work horse" capability of the Atlas-Centaur vehicle. A Mars space probe was discussed briefly; it could be launched by the Centaur and would be designed to take pictures and transmit data back to Earth. A favorable launching time would occur late this year and then again in 1962.

Manned space travel is impeded by the presence and effects of solar flares. It was suggested that the shielding requirement to protect against solar flares would be of the same order of magnitude as that required for protection from a nuclear reactor. This implies that nuclear-powered space vehicles may be the only practical means to attain interplanetary travel. Mr. Ford indicated that the return trip would be difficult to control with the precision required to effect re-entry into Earth's atmosphere. If the re-entry angle is too large, the re-entry vehicle burns, and if the trajectory is too high, the possibility of running out of propellant exists. Reserve propellant is required to correct for expected errors.

▶ Featured at the February 25 space/science lecture were two papers, **"Winged Recoverable Booster Characteristics"** by **D. J. Jones** and **J. O. Tearnen** of Convair-Astronautics (presented by Mr. Jones), and **"Methods and Economics of Recovering Boosters for Orbital Vehicles"** by **Paul R. Shipps.**

The first paper was a consideration of the engineering problems involved in winged recoverable rocket booster design. Fundamental problems encountered in aerodynamics, thermodynamics, structures materials, and power plants were discussed. Methods of approach to the solution of the various critical problem areas were outlined and some general results were presented. The discussion was limited mainly to winged VTO booster vehicles using rocket engines for launch power plants. Economic considerations in configuration selection were briefly discussed.

The second paper, by Mr. Shipps, covered system and economic aspects of recovering air-breathing boosters for 10-20-ton satellites. Comparative utilization data, trajectory and operational differences, and overall system costs were treated. Expendable rocket systems were shown to be most economical if less than several hundred payloads are placed in orbit, highly recoverable air-breathing systems most economical for larger numbers of missions.

FRANK PARRY
Secretary
ANTHONY W. TEMPLIN
Program & Meetings Chairman

San Francisco Section

Power Sources

The March 17 dinner meeting presented **Dr. J. H. Fisher,** Manager of Energy Research Division, Electro-Optical Systems, Inc., discussing **"The Promise of Power for the Future."**

Dr. Fisher noted that today there are essentially four large sources of power: (1) the fossil field, (2) the uranium-thorium reserve, (3) solar radiation, and (4) the deuterium in the oceans of the world. He noted that the demands of society, the level of technical performance of that society, its monetary wealth and social atmosphere are the main pressures contributing to the development of new power sources. Dr. Fisher observed that the world is under no immediate pressure to abandon present exploitations of the fossil field because this source is expected to last another 200 years or so. It appears inevitable, however, that new sources eventually will have to be developed either because of exhaustion of the easily obtained fossil power or because of

(*Continued on page 106*)

CALIFORNIA

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- **U. S. Naval Ordnance Laboratory at Corona:** Developers of guidance and telemetry systems and other missile system components. Researchers in such fields as IR spectroscopy, magnetism and semiconductors.
- **U. S. Naval Radiological Defense Laboratory at San Francisco:** The nation's only major center for research on nuclear effects and development of counter measures.
- **U. S. Navy Electronics Laboratory at San Diego:** One of the Navy's largest organizations engaged in the research and development of radar, sonar, radio and acoustics.

*These positions are in the Career Civil Service.

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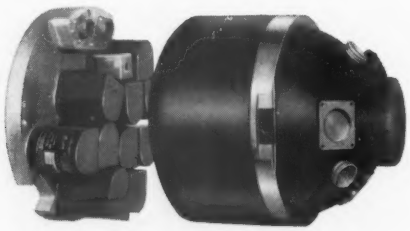

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AERO/SPACE Reviews

. . . current literature of aeronautical engineering and space technology

THIS SECTION reviews important periodicals, technical and research reports, and books received in the IAS Library in order to provide basic documentation for engineers and scientists.

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For a listing of the principal periodicals received in the IAS Library, please refer to the January, 1959, issue.

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Acoustics, Sound, Noise

Industrial Acoustics: Sounds at Work. Vincent Salmon. *SRI J.*, 1st Quart., 1960, pp. 4–10. Discussion of some future uses of sound waves in nondestructive testing of adhesive or welded bonds, detection of viscosity, grain size, elastic constants, or flaws in solids. The application of this testing method to aircraft is shown and the use of sound in measuring procedures, chemical and physical processing methods, as well as in metals' technology, is presented.

Recent Studies of Noise Problems. G. G. Parfitt. *Brit. J. Appl. Phys.*, Feb., 1960, pp. 53–57. 14 refs. Review of recent work on various aspects of acoustic noise. Discussion included parameters of noise which are important in determining the subjective loudness, the possible damaging effects on human hearing, the influence on working efficiency, the annoyance caused in residential and working communities, the difficulties in making measurements of noise from aircraft to the high degree of accuracy often required, results of measurements, and an analysis of the noise from automotive diesel engines.

Resonance Sound Absorber with Yielding Wall. S. N. Rzhevkin. (*Zhur. Tekh. Fiz.*, No. 4, 1946, pp. 381–394.) *U.S., NACA TM 1273*, May, 1951. 26 pp. 15 refs. Translation. Investigation of a single-sheet resonance system for normal incidence of sound. The effect of sympathetic vibration of the resonator front wall on sound absorption is studied in detail.

Vlastnosti Zdrojů Hluku v Letadlech. Jaroslav Němec. *Zpravodaj VZLÚ*, Nov.-Dec., 1958, pp. 15–20. In Czechoslovak. Discussion of the two main sources of aircraft noise—i.e., propellers and engines. The effects of these sources, in addition to some structural considerations, on small and transport aircraft are studied, and recommendations for noise control are given.

Field Measurement of Community Noise Exposure Near Hanscom Air Force Base, Mass. A. C. Pietrasanta. *USAF WADC TN 58-163 [AD 155879]*, Aug., 1958. 23 pp.

Zvukové Izolace v Letadlech. Jaroslav Němec. *Zpravodaj VZLÚ*, Jan., 1959, pp. 3–7. In Czechoslovak. Presentation of the factors of noise control in aircraft. The consideration in the choice of the type of insulation, materials, and construction are discussed. Measurement results showing the effect of insulations on the composition of the noise spectra are included.

Aerodynamics, Fluid Mechanics

Aerothermochemistry, Dissociation, Ablation

A Theoretical Study of Stagnation-Point Ablation. Leonard Roberts. *U.S., NASA TR R-9*, 1959. 11 pp. Supt. of Doc., Wash., $0.30. Analysis of the shielding mechanism which reduces the stagnation-point heat transfer when ablation takes place at the surface. It is found that the effective heat capacity of the ablation material increases linearly with stream enthalpy.

Ablation of Reinforced Plastics in Supersonic Flow. G. W. Sutton. (*G-E MOSD AORM 3*, July 26, 1957.) *J. Aero/Space Sci.*, May, 1960, pp. 377–385. USAF-sponsored study.

Numerical Calculation of Absolute Bremsstrahlung Intensity for a Fully Ionized Fully Dissociated Hydrogenic Gas. G. S. Janes and H. Koritz. *J. Appl. Phys.*, Mar., 1960, pp. 525–528. USAF-supported presentation of a numerical calculation using the approximate relationships of Kirkpatrick and Weidmann. A calibration method is presented for the measurement of absolute bremsstrahlung intensities which continually compensates for the errors present in most calibration procedures.

Aerothermodynamics

Effects of Mach Number and Wall-Temperature Ratio on Turbulent Heat Transfer at Mach Numbers from 3 to 5. Thorval Tendeland. *U.S., NASA TR R-16*, 1959. 15 pp. 19 refs. Supt. of Doc., Wash., $0.30. Presentation of test results showing that the ratio of wall to free-stream temperature has an appreciable effect on the heat-transfer rate, and that the increase in heat-transfer rate with decreasing wall-temperature ratio is equivalent to the increase in turbulent skin-friction coefficient.

Stagnation-Point Heat-Transfer Measurements in Hypersonic, Low-Density Flow. S. E. Neice, R. W. Rutowski, and K. K. Chan. *J. Aero/Space Sci.*, May, 1960, pp. 387, 388. Presentation of test results and comparison with the theory. The theoretical predictions of the effect of shock-generated vorticity on stagnation-point heat transfer appear to be borne out by the experimental results.

Measurements of Skin Friction of the Compressible Turbulent Boundary Layer on a Cone with Foreign Gas Injection. C. C. Pappas and A. F. Okuno. (*IAS 27th Annual Meeting, New York, Jan. 26–29, 1959, Report 59-78.*) *J. Aero/Space Sci.*, May, 1960, pp. 321–333. 15 refs.

The Influence of Aerodynamic Heating on the Structural Design of Aircraft. M. W. Rubesin. (*NATO AGARD 8th Structures & Materials Panel, Copenhagen, Oct. 20–25, 1958.*) *NATO AGARD Rep. 207*, Oct., 1958. 22 pp. 20 refs. Presentation of simplified expressions for determining the heat transfer to several aircraft shapes at hypersonic speeds. These expressions are then used to examine the basis for choosing a particular class of aircraft structures to withstand the aerodynamic heating.

Cooling of Structures in High Speed Flight. Appendix I—Theory of Electrical Analogy and Description of Ames Electrical Heat-Flow Analog. Appendix II—Procedure for Solving Simplified Equations of Wing Leading-Edge Temperature. C. B. Neel. (*NATO AGARD 8th Structures & Materials Panel, Copenhagen, Oct. 20–25, 1958.*) *NATO AGARD Rep. 210*, Oct., 1958. 29 pp. 15 refs. Discussion of various ways of cooling critical areas, emphasizing radiation, heat sink, and conduction cooling. Temperature distributions through a typical structure are shown for transient heating conditions. A method of computing wing leading-edge temperatures including the effects of radiation, heat capacity, and heat conduction for arbitrary flight conditions is introduced, and comparisons are made with electrical-analog calculations.

Boundary Layer

Some Developments in Boundary Layer Research in the Past Thirty Years. H. Schlichting. (*3rd Lanchester Memorial Lecture, London, Nov. 26, 1959.*) *RAeS J.*, Feb., 1960, pp. 64–79. 78 refs. Discussion covering the transition from laminar to turbulent flow, boundary-layer control for high lift and low drag of airfoils, aerodynamic heating at high Mach numbers, and boundary layer effects on swept wings and on rotating bodies.

Wings That Won't Stall. J. S. Kishi. (*ASME Semi-Annual Meeting, St. Louis, June 14–18, 1959.*) *Mech. Eng.*, Apr., 1960, pp. 81–83. Abridged. Presentation of test results showing that turbulence, and hence stall, can be controlled by a suction pulling air through perforations in the wing's upper surface, resulting in slower take-offs and landings.

The Occurrence and Development of Boundary-Layer Separations at High Incidences and High Speeds. H. H. Pearcey. *Gt. Brit., ARC R&M 3109* (Sept., 1955) 1960. 15 pp. 16 refs. BIS, New York, $0.99. Description of the manner in which the onset of the effects of boundary-layer separation varies with Mach number for two-dimensional airfoils. The influence of section shape is discussed, and a qualitative description is given of the mechanism underlying the development of the separated flow and its effects.

An Experiment on the Stability of Hypersonic Laminar Boundary Layers. Anthony Demetriades. (*GALCIT Memo. 43*, May 15, 1958.) *J. Fluid Mech.*, Mar., 1960, pp. 385–396. 20 refs. Army-supported research.

Skin-Friction Measurements in Incompressible Flow. D. W. Smith and J. H. Walker. *U.S., NASA TR R-26*, 1959. 35 pp. 12 refs. Supt. of Doc., Wash., $0.45. Discussion of experiments conducted to measure, in incompressible flow, the local surface-shear stress and the average skin-friction coefficient for a turbulent boundary layer on a smooth, flat plate having zero pressure gradient. The results show that the "universal skin-friction constants," proposed by Coles, approach asymptotically a constant value at Reynolds numbers exceeding 21 million.

Control Surfaces

Aerodynamic Damping at Mach Numbers of 1.3 and 1.6 of a Control Surface on a Two-Dimensional Wing by the Free-Oscillation Method. W. J. Tuovila and R. W. Hess. *U.S., NASA TN D-116*, Feb., 1960. 21 pp. Discussion of experimental methods and models used to determine the aerodynamic damping characteristics of a control surface. The test results are compared with those calculated by two- and three-dimensional oscillating air-force theories.

The Longitudinal Frequency Response to Elevator of an Aircraft Over the Short Period Frequency Range. Appendix I—Transfer Functions for the General Longitudinal Case. Appendix II—Range of Validity of the Approximate Values of the Short Period Stability Parameters B and C. D. M. Ridland. *Gt. Brit., RAE TN Aero. 2647*, Sept., 1959. 53 pp. Presentation of formulas for the evaluation of aircraft longitudinal frequency response characteristics. The simple short period frequency response is illustrated for three different types of aircraft, and the effects of neglecting elevator lift and speed variations associated with the phugoid motion are separately determined and discussed.

An Experimental Investigation to Determine the Effect of Speed-Brake Position on the Longitudinal Stability and Trim of a Swept-Wing Fighter Airplane. R. T. Taylor. *U.S., NASA TN D-246*, Feb., 1960. 46 pp. Description of wind tunnel tests indicating that an adequate drag increment with an acceptable pitch increment is obtained when both the side and underfuselage speed brakes are extended and with the underfuselage brakes mounted in their most forward position. The results of brief lateral control tests concerning (1) the effect of a plain spoiler mounted ahead of the aileron, and (2) the effect of blunting the aileron trailing edge are also included.

The Estimation of Tail Loading Due to Elevator-Induced Pitching Manoeuvres. III. P. F. Richards. *Aircraft Eng.*, Mar., 1960, pp. 77–83. Analysis of the checked maneuver and presentation of a method for determining flight loads to cover all pitching maneuvers in a form suitable for amendment of civil airworthiness regulations.

Free-Flight Investigation at Mach Numbers Between 0.5 and 1.7 of the Zero-Lift Rolling Effectiveness and Drag of Various Surface, Spoiler, and Jet Controls on an 80° Delta-Wing Missile. Appendix—Wing-Jet Thrust-Magnification Ratio. E. D. Schult. *U.S., NASA TN D-205*, Feb., 1960. 47 pp. 20 refs. Presentation of test results indicating that all controls are satisfactory roll-producing devices except the canards located immediately forward of the main wings and spoilers at other than trailing-edge locations.

Flow of Fluids

Turbulent Flow and Heat Transfer Rates in Non-Newtonian Fluids. A. B. Metzner and P. S. Friend. (*Ind. & Eng. Chem.*, July, 1959, pp. 879–882.) *U. Del. Dept. Chem. Eng. Final Rep. (AFOSR TR 59-143)*, Dec., 1959. 6 pp. 18 refs. Reprint. Analysis of the flow characteristics of non-Newtonian systems flowing through smooth round tubes. The application of the results to the prediction of heat-transfer rates by means of the analogy between heat and momentum transfer is discussed.

An Experimental Investigation of the Dynamics of a Self-Propelling Body in a Tube. Henry Lopez. *Rensselaer Polytech. Inst. Dept. Aero. Eng. TR AE5903*, Dec. 8, 1959. 14 pp. Study of the motion of a self propelled vehicle in a duct open at both ends and in a duct closed at one end, including velocity and acceleration calculations.

The Motion of a Self-Propelled Body in a Tube. H. J. von Keszycki. *Rensselaer Polytech. Inst. Dept. Aero. Eng. TR AE5905*, Dec. 29, 1959. 54 pp. Theoretical and experimental study of the motion of an axial-flow ducted fan used as a vehicle traveling in a tube. The applicable equation of motion for the vehicle in the tube is derived and solved analytically, and the experimental and theoretical results are compared.

Analogia Hydrauliczna Przepływu Gazu Ściśliwego. Andrzej Kowalewicz. *Tech. Lotnicza*, Nov.-Dec., 1959, pp. 171–176. In Polish. Analysis covering the basic concepts of the hydraulic analogy for one- and two-dimensional compressible gas flows.

An Approximate Theory of Base Pressure in Two-Dimensional Flow at Supersonic Speeds. Appendix I—The Change in Boundary Layer Thickness When the Main Stream Passes Through an Expansion Fan. Appendix II—The "Transition" from a Boundary Layer to a Mixing Region. F. N. Kirk. *Gt. Brit., RAE TN Aero. 2377*, Dec., 1959. 27 pp. 12 refs. Presentation of a theory facilitating the qualitative prediction of the effects of a boundary layer, of bleed air, and of boat-tailing.

Virtual Masses of Some Curvilinear Contours Immersed in Detached Flow. S. I. Parkhomovskii. (*Prikl. Mat. i Mekh.*, May-June, 1959, pp. 585–588.) *PMM—Appl. Math. & Mech.*, No. 3, 1959, pp. 827–833. Translation. Study covering the impact of a detached flow of an ideal incompressible gas upon the family of curves $L(m, \nu)$.

On Stokes Flow About a Torus. W. H. Pell and L. E. Payne. *U.S., NBS Rep. 6546*, Sept. 22, 1959. 23 pp. 11 refs. USAF-supported presentation of a method used to solve the Stokes flow problem for certain axially symmetric bodies, with the velocity at infinity, uniform and parallel to the axis of symmetry. The analysis is an extension of previous work, removing the assumption that, in each of the bodies considered, the meridional section intercepts a segment of the axis of symmetry. The particular case of the Stokes flow about a torus is considered.

Comments on the Paper by A. Ferri, "Recent Theoretical Work in Supersonic Aerodynamics at the Polytechnic Institute of Brooklyn." B. M. Bulakh. (*Prikl. Mat. i Mekh.*, May-June, 1959, pp. 576–580.) *PMM—Appl. Math. & Mech.*, No. 3, 1959, pp. 811–818. Translation.

Boundary-Layer Displacement Effects in Air at Mach Number of 6.8 and 9.6. Appendix A—Leading-Edge-Thickness Effects. Appendix B—Effect of Variable γ and Gaseous Imperfections. Appendix C—Skin Friction of a Flat-Plate Wing with Delta Plan Form Including Boundary-Layer Displacement Effect. Appendix D—Skin Friction of a Flat-Plate Delta Wing with Boundary-Layer Transition. M. H. Bertram. *U.S., NASA TR R-22*, 1959. 32 pp. 27 refs. Supt. of Doc., Wash., $0.40. Presentation of measurements for pressure gradients induced by a laminar boundary layer on a flat plate in air at a Mach number of 9.6 and for the drag of thin wings at a Mach number of about 6.8 and zero angle of attack. Theoretical considerations are discussed and theoretical results are compared with those obtained experimentally.

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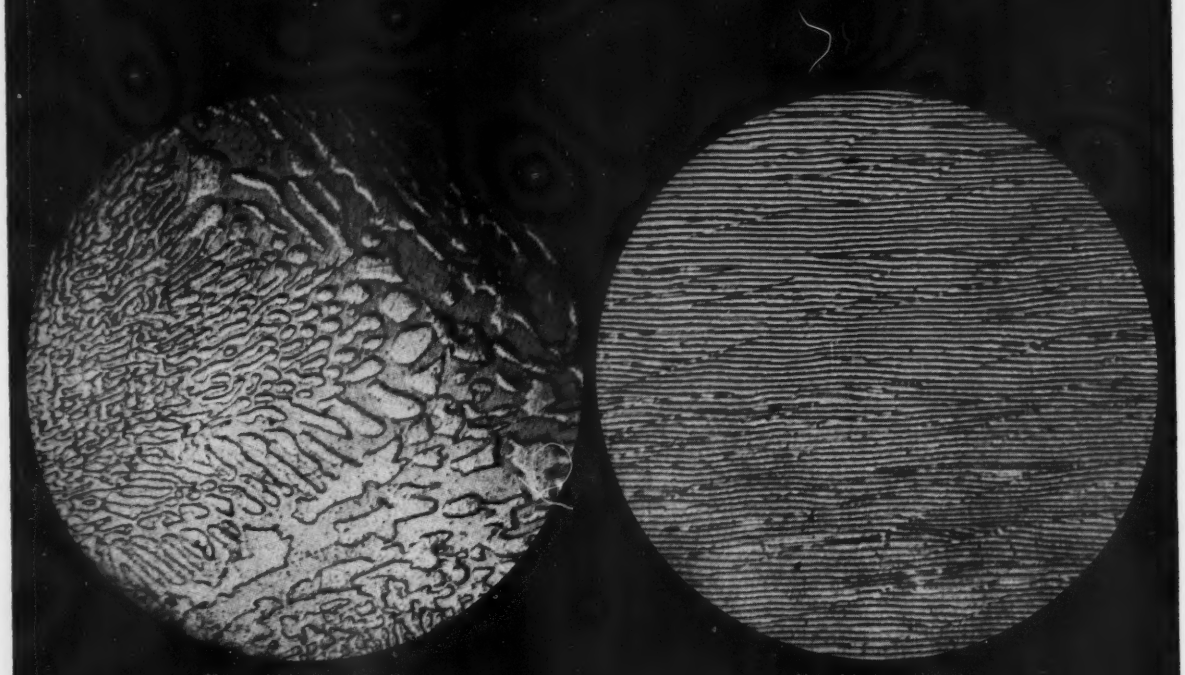

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UAC RESEARCH

Flow of Highly Rarefied Gases Around Oscillating Surfaces. N. T. Pashchenko. (*Prikl. Mat. i Mekh.*, July-Aug., 1959, pp. 760–765.) *PMM—Appl. Math. & Mech.*, No. 4, 1959, pp. 1081–1089. Translation. Study and determination of the total force acting on a unit surface, which performs small unsteady motions while moving forward. Its projection in direction corresponding to normal pressure and friction is also determined. An attempt is made to assess the validity of analysis of flows around concave surfaces with the usual free-molecular assumptions. It is found that the expression for the additional pressure due to oscillation agrees, up to a multiplicative constant, with a known formula of the "piston theory."

On the Distribution Function for Dissipative Processes in a Rarefied Relativistic Gas. S. S. Moiseev. (*Zhurnal Teoret. i Exper. Fiz.*, Aug., 1959, pp. 553, 554.) *Sov. Phys - JETP*, Feb., 1960, pp. 391, 392. Translation. Discussion of the motion of a rarefied gas or of a gas with a large flow gradient, considering the heat flow and the tensor viscous stresses in addition to the independent parameters (mean velocity, density, and temperature).

On the Statistical Theory of Turbulence. B. I. Davydov. *Sov. Phys. - Dokl.*, Feb., 1960, pp. 779–781. Translation. Development of equations for a turbulent flow, bounded by solid walls, where the source of turbulence is in the boundary layer which essentially determines the entire structure of the turbulent flow.

On the Statistical Dynamics of an Incompressible Turbulent Fluid. B. I. Davydov. *Sov. Phys.-Dokl.*, Feb., 1960, pp. 769–772. Translation. Analysis of the development of turbulence at high values of the Reynolds number, considering primarily a flow bounded by solid walls, and of its characteristic boundary layer with a logarithmic mean velocity profile.

Measurements of the Effect of Molecular Diffusivity in Turbulent Diffusion. W. R. Mickelsen. *J. Fluid Mech.*, Mar., 1960, pp. 397–400. Presentation of experimental results showing that, for long diffusion times, accelerated molecular diffusion is negligible, so that molecular diffusion makes only an independent contribution to the total dispersion.

Internal Flow

Analiza i Ocena Przydatności Metod Określania Przelotności Palisad Łopatkowych. Jerzy Krzyzanowski. *Arch. Budowy Maszyn*, No. 4, 1959, pp. 595–621. 15 refs. In Polish, with summaries in English and Russian. Presentation of current expressions for estimating the flow capacity of turbine cascades. The magnitude of the error involved in the use of classic and more exact forms of the formulas used is compared.

Výpočet Obtékání Lopatkových Mříží s Tenkými Silně Prohnutými Profily. Jan Polášek. *Aplikace Matematiky*, No. 3, 1958, pp. 325–347. In Czechoslovak, with summaries in Russian and German. Presentation of a practical method for calculating the potential, incompressible flow in cascades of thin, arbitrarily curved profiles.

Flow in Axial Blade. Takefumi Ikui. *JSME Bul.*, Feb., 1960, pp. 29–35. Investigation of the flow behavior in an impeller and guide vane of an axial blower, using silk tufts for visualization purposes.

Berechnung der Potentialströmung für ein ebenes Spalt-Schaufelgitter. František Slepička. *Aplikace Matematiky*, No. 4, 1959, pp. 255–290. 38 refs. In German. Calculation of the potential flow in slotted cascades, based on the classical method of singularities.

Experimental Study on Cavitation in Centrifugal Pump Impellers. Shungo Minami, Kyoji Kawaguchi, and Tetsuo Homma. *JSME Bul.*, Feb., 1960, pp. 19–29. 12 refs.

Experimental Study of Zero-Flow Ejectors Using Gaseous Nitrogen. W. L. Jones, H. G. Price, Jr., and C. F. Lorenzo. *U.S., NASA TN D-203*, Mar., 1960. 23 pp. Investigation of two ejectors to determine the factors important in the design of such ejectors for altitude testing of rocket engines. Experimental maximum ejector contraction area ratios and starting performance are given for a range of ejector inlet Mach numbers from one to ten.

Flow of a Gas Jet Out of a Channel Past a Flat Plate. V. L. Troshin. (*Prikl. Mat. i Mekh.*, July-Aug., 195£, pp. 766–769.) *PMM—Appl. Math. & Mech.*, No. 4, 1959, pp. 1090–1096. Translation. Extension, based on Falkovich's approach, of Chaplygin's method for the solution of the gas jet problem to the case of jets having a number of characteristic speeds greater than one.

Jet Flaps & Wings

Effects of a Lower Surface Jet on the Lift-Drag Ratio of a 45° Sweptback Wing at a Mach Number of 2.01. E. J. Landrum. *U.S., NASA TN D-183*, Mar., 1960. 40 pp. Presentation of test results indicating that the most effective jet inclinations appear to be those nearer the vertical, with decreasing effectiveness as the jet is inclined rearward.

Performance

Let's Talk Mach. Michael Barna, Jr. *Air Line Pilot*, Mar., 1960, pp. 13–20. Discussion covering a definition of the Mach number analyzed in terms of day to day operation, including presentation of some modern data on airspeeds.

The Approximate Solution of the Equations of a Motion of an Airplane Moving in a Vertical Plane. E. F. Trombley. *J. Aero/Space Sci.*, May, 1960, pp. 394–396. Presentation of an approximate solution for a constant Mach number climb in the variable temperature region and the acceleration in a straight line at constant altitude.

Stability & Control

Experimental Determination of the Effect of Frequency and Amplitude of Oscillation on the Roll-Stability Derivatives for a 60° Delta-Wing Airplane Model. Appendix—Stability Calculations. L. R. Fisher. *U.S., NASA TN D-232*, Mar., 1960. 49 pp. Investigation showing that the rolling and yawing moments due to both rolling velocity and rolling acceleration are highly dependent on frequency at angles of attack higher than 16°. The analysis reveals that inclusion of the acceleration derivatives in the equations of motion causes significant changes in the period and damping for a representative airplane.

Determination of Nonlinear Pitching-Moment Characteristics of Axially Symmetric Models from Free-Flight Data. Appendix—Series Expansion of the Frequency Equations. M. S. Rasmussen. *U.S., NASA TN D-144*, Feb., 1960. 51 pp. Analysis of the pitching and yawing motion of a symmetrical missile with a cubic restoring moment. A rapid method of estimating the cubic restoring moment coefficients from the observed frequency and amplitudes of two independent sets of free-flight data is presented.

Wing-On and Wing-Off Longitudinal Characteristics of an Airplane Configuration Having a Thin Unswept Wing of Aspect Ratio 3, as Obtained from Rocket-Propelled Models at Mach Numbers from 0.8 to 1.4. C. L. Gillis and A. J. Vitale. *U.S., NASA TN D-7*, Mar., 1960. 42 pp. 13 refs. Presentation of aerodynamic derivatives defining the static and dynamic longitudinal stability, control, trim, and drag characteristics of the configuration over a Mach number range from 0.8 to 1.4. For some of the aerodynamic derivatives the separate effects of the wing, tail, and fuselage are determined.

The Rolling Moment Due to Sideslip of Swept Wings at Subsonic and Transonic Speeds. Appendix A—Simplified Method of Estimating C_{l_α}. Appendix B—20-Vortex Solution for the Rolling Moment Due to Sideslip. E. C. Polhamus and W. C. Sleeman, Jr. *U.S., NASA TN D-209*, Feb., 1960. 81 pp. 47 refs. Analysis of experimental results on the effects of wing sweep, aspect ratio, taper ratio, and dihedral on the rolling moment due to sideslip of wing-fuselage configurations up to Mach numbers of about 0.95. New methods are presented for estimating the effects of compressibility and wing geometry on the rolling moment due to sideslip.

Low Speed Wind Tunnel Tests on the de Havilland Sea Venom with a Part-Span Sharp Wing-Leading-Edge Extension. M. B. Guyett. *Gt. Brit., RAE TN Aero. 2644*, Sept., 1959. 17 pp. Presentation of measurements of the effect of a part-span sharp leading-edge extension on the longitudinal stability of a Venom half-model.

Wings & Airfoils

Boundary-Induced Downwash Due to Lift in a Two-Dimensional Slotted Wind Tunnel. S. Katzoff and R. L. Barger. *U.S., NASA TR R-25*, 1959. 19 pp. Supt. of Doc., Wash., $0.35. Derivation of a solution for the complete tunnel-interference flow for a lifting vortex in a two-dimensional slotted tunnel.

The Downwash of the Flow Behind the Swept Vortex of Finite Span for Non-Laminar Motion. E. A. Biriukov. (*Prikl. Mat. i Mekh.*, May-June, 1959, pp. 583, 584.) *PMM—Appl. Math. & Mech.*, No. 3, 1959, pp. 823–826. Translation. Presentation of formulas for calculating the downwash in an ideal incompressible fluid behind a wing of large aspect ratio and small angle of sweep for the case when the circulation, variable along the span of the wing, also varies harmonically with time.

Podobnost Obtékání Profilů při Transsonickém Proudění. Václav Strach. *Zpravodaj VZLÚ*, Sept.-Oct., 1958, pp. 11–14. In Czechoslovak. Study covering similarity rules of transonic flows over thin airfoils. An example is presented to illustrate the applicability of the similarity theory. Equations for calculating the lift coefficient of a given airfoil and of a family of airfoils are given, and the methods for determining the drag coefficient are indicated.

Conical Camber for Delta Wings. J. W. Addington. *Aeronautics*, Mar., 1960, pp. 28–30. Discussion of some reasons behind the use of conical camber. Test results comparing cambered and uncambered wings of the same thickness are studied.

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Control Systems, Automatic Pilots

Flight Investigation of Pilot's Ability to Control an Airplane Having Positive and Negative Static Longitudinal Stability Coupled with Various Effective Lift-Curve Slopes. R. F. Brissenden, W. L. Alford, and D. L. Mallick. *U.S., NASA TN D-211*, Feb., 1960. 20 pp. Study including the determination of the ranges of possible human-pilot control of the variable-stability airplane at various stability levels coupled with various reduced effective life-curve slopes.

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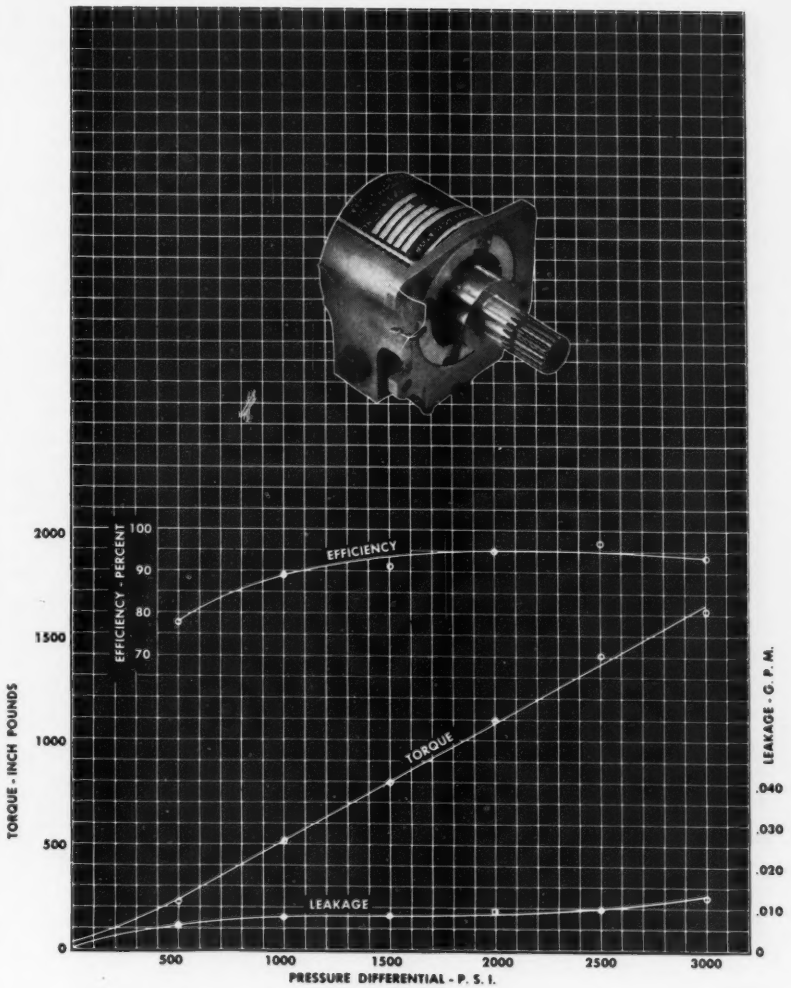

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Landing, Landing Loads

Special Issue: Flight Systems Survey. *Flight*, Feb. 19, 1960, pp. 233–246. *Partial Contents*: Automatic Landing: A Review of Projects and Progress. BEA and Automatic Landing. BOAC and Automatic Landing. Pye ILS and Automatic Landing, B. Williams. Standard Telephones and ILS. The ARB and Automatic Landing.

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Shock Strut Valve Halves Pulse Loads. Emanuel Schnitzer. (*U.S., NACA TN 4387*, Sept., 1958.) *Space/Aeronautics*, Apr., 1960, pp. 93, 94, 96–98. Evaluation of bandpass shock strut designs and comparison with conventional fixed-orifice struts.

Emergency Stopping of Aircraft Which Over-Run Airfield Runways. J. Thomlinson. (*NATO AGARD 13th Flight Test Panel, Copenhagen, Oct. 20–25, 1958.*) *NATO AGARD Rep. 226*, Oct., 1958. 45 pp. Discussion of various ways that have either been tried or proposed for stopping aircraft which overrun an airfield runway. Soft ground overrun area schemes, mechanical schemes, and aircraft "catching" devices, as well as the mechanics involved, are considered.

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Development of Improved Flight Helmet Liner. *USAF WADC TR 59-435*, Oct., 1959. 17 pp. Evaluation of various low-density plastic foam systems to be used for a padding helmet liner providing maximum comfort with greatest protection against shock and impact. Polyurethane foam systems are shown to be capable of providing the desired combination of properties, utilizing techniques adaptable to production processing.

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Studies in Human Isolation. S. J. Freedman and Milton Greenblatt. *USAF WADC TR 59-266*, Sept., 1959. 46 pp. 34 refs. Description of perceptual and cognitive distortions and disorientations differentially induced by eight-hour experimental sessions involving (a) non-patterned visual and auditory input combined with social isolation, (b) visual deprivation combined with auditory nonpatterning and social isolation, and (c) social isolation alone.

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Influence of Prior Body Cooling with Air on Human Heat Tolerance. J. H. Veghte and Paul Webb. *USAF WADC TR 59-350*, Sept., 1959. 13 pp. Investigation conducted with three experienced subjects to determine the feasibility of using a ventilating suit as a vehicle for body cooling prior to heat exposures. The results confirm the applicability of this approach for prior body cooling and extension of tolerance times to a heat stress.

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A Device for Measuring Gross Motor Behavior in Primates. D. W. Ormiston, F. H. Rohles, Jr., and M. E. Grunzke. *USAF WADC TN 59-353*, Oct., 1959. 4 pp.

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An Exploratory Study of Prolonged Intermittent Photic Stimulation. H. S. Alexander and W. D. Chiles. *USAF WADC TR 59-715*, Nov., 1959. 6 pp. Investigation of human resistance to the effects of intense flashing light for prolonged periods of time. No adverse effects were observed, but all test subjects displayed electroencephalographic responses to the lights.

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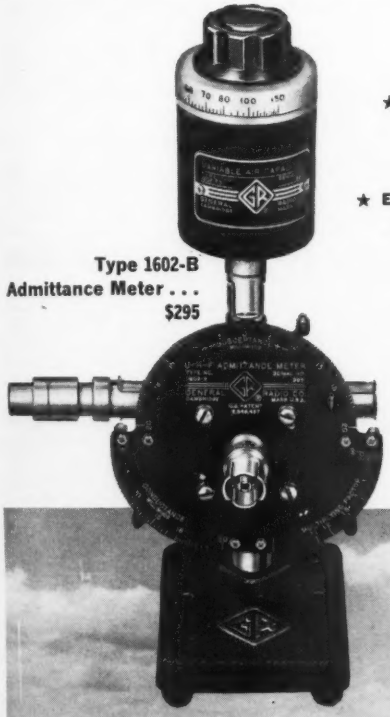

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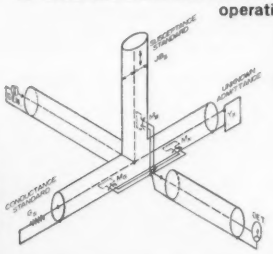

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Survey of Human Dynamics Data and a Sample Application. J. W. Senders. *USAF WADC TR 59-712*, Nov., 1959. 12 pp. 11 refs.

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Techniques for the Optimum Synthesis of Multipole Control Systems with Random Processes as Inputs. H. C. Hsieh and C. T. Leondes. *U. Calif. Dept. Eng. UCLA Rep.* (*AFOSR TN 59-1132*), Sept., 1959. 39 pp. Presentation of a synthesis procedure in which the design criterion employed is the minimum mean-square error between actual outputs and ideal outputs of the system. A set of integral equations is obtained, which can be converted into algebraic equations through transformation. By solving these equations and using the method of undetermined coefficients, the transfer functions of the compensation can be uniquely determined.

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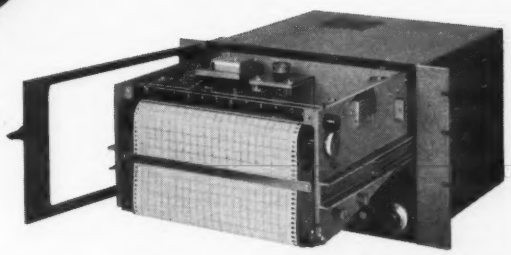

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Group Refractive Index of the Ionosphere at Low Frequency. Y. S. N. Murty and S. R. Khastgir. *J. Atmos. & Terrestrial Phys.*, No. 4, Feb., 1960, pp. 309–314.

Terrestrial Propagation of Very-Low-Frequency Radio Waves; A Theoretical Investigation. J. R. Wait. *J. Res., Sect. D - RP*, Mar.-Apr., 1960, pp. 153–204. 87 refs. Presentation of the waveguide mode theory. The model of a flat earth with a sharply bounded and homogeneous ionosphere is treated for both vertical and horizontal dipole excitation. The properties of the modes are discussed and the influences of earth curvature, the earth's magnetic field, antipodal effects, and resonator type oscillations are considered.

Fading and Attenuation of High-Frequency Radio Waves Propagated Over Long Paths Crossing the Auroral, Temperate and Equatorial Zones. K. C. Yeh and O. G. Villard, Jr. *J. Atmos. & Terrestrial Phys.*, No. 4, Feb., 1960, pp. 255–270. 22 refs. USAF-supported research.

A Proposed Tropospheric Scatter Communications Equipment Configuration for Time Diversity Reception. C. F. Huntington. *USAF RADC TN 59-304*, Dec., 1959. 18 pp. 12 refs. Discussion of an equipment configuration which facilitates the use of time diversity with no decrease in channel capacity and no appreciable decrease in transmission speed.

Equipment

Hydraulic & Pneumatic

Hydraulic Swivel Systems. G. M. Bagnard. *Mach. Des.*, Mar. 17, 1960, pp. 160–164. Discussion of the geometric characteristics of swivel joints, the four basic types of swivel-systems, and their advantages and applications.

Some Factors Influencing the Stability of Piston-Type Control Valves. G. J. Noton and D. E. Turnbull. *IME Proc.*, No. 40, 1958, pp. 1065–1077; Communications, pp. 1078–1081. Investigation of the dynamic behavior of a common type of hydraulic position-control system in which continuous oscillation occurs due to insufficient damping. Frequencies of oscillation and pressure fluctuations are studied.

Fuels & Lubricants

Fuel May Cool Manned Flights at Mach 4. Michael Yaffee. *Av. Week & Space Tech.*, Mar. 14, 1960, pp. 89, 91, 93, 96, 97. Discussion of the chemical reactions of endothermic (heat absorbing) fuels, the design problems arising from their

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By R. L. Carroll, *Bell Aircraft Corp.* A simple, direct, new approach: 1) lift is shown to be directly dependent on power; 2) rocket power is regarded as the logical lift source; and 3) transition is made at this point to questions of powered flight with aerodynamic lift. *1960. 275 pages. $8.50.*

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THEORY OF MECHANICAL VIBRATION

By Kin N. Tong, *Syracuse University*. Theory-centered rather than problem-centered, it covers linear theory and its extensions, with up-to-date mathematical methods and techniques. Stresses engineering applications of the theory. *1960. 348 pages. $9.75.*

SURFACE EFFECTS ON SPACECRAFT AND MATERIALS

Edited by F. J. Clauss, *Lockheed Aircraft Corp.* Record of a symposium, covering methods for calculating required characteristics, available materials, laboratory techniques for measuring radiation characteristics, and effects of space environment on behavior of materials. *1960. 404 pages. $11.50.*

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use, and the programs aimed at developing these fuels and the power plants using them.

Pohonné Hmoty Budoucnosti. Jan Krotký. *Zpravodaj VZLÚ*, Jan., 1959, pp. 23–25. In Czechoslovak. Survey of the development of jet fuels. The properties, advantages, and limitations of various types are discussed.

Free Fall and Evaporation of JP-1 Jet Fuel Droplets in a Quiet Atmosphere. Appendix A—**Revised Computer Program.** H. H. Lowell. *U.S., NASA TN D-199*, Mar., 1960. 47 pp. Investigation concerning the problem of the dispersion of jet fuel jettisoned at altitude. It is found that temperature is the principal variable controlling the evaporation rate and that little or no fuel in droplet form will evaporate when the sea-level air temperature is 0° C. or less.

Fuel Fungi. J. M. Leonard. *Naval Res. Rev.*, Feb., 1960, pp. 16–18. Discussion of the problems created by bacteria and fungi growing in kerosene-like fuel. Factors supporting microbial growth and possible remedies are discussed.

High Temperature Fluids for the B-58. G. H. Craig. *Appl. Hydraulics & Pneumatics*, Mar., 1960, pp. 116, 118. Discussion of the properties of a fluid developed for a system demanding flows to 120 g.p.m. at pressures to 3,000 psi with a maximum operating temperature of 350°F. Oxidation, flammability, and hydrolysis characteristics, as well as materials compatibility, fluid replacement, and hazards to personnel are discussed.

Thermodynamic Data of Propellant Ingredients. P. Tavernier. (*Mém. Poudres*, No. 38, 1956, pp. 301–336.) *Gt. Brit., MOS T1L/T4811*, Sept., 1959. 33 pp. Translation. Presentation of data amplifying the Pike tables to include the organic and inorganic substances which may constitute ingredients in recently developed propellants. The methods presented in building up the tables may be directly applied to other inorganic additives in propellants.

Combustibili Folositi la Propulsia Rachetelor. Pascal Popescu and Bartolomeu Vasilescu. *Rev. Transp.*, Nov., 1959, pp. 480–487. In Rumanian. Outline of the basic requirements, as well as criteria for the selection of rocket fuels. The properties of the main products are presented and manufacturing, handling, and storage problems are discussed.

The Apparent Calorimetric Value and Volume of the Gases Produced by the Decomposition of Propellants. P. Tavernier. (*Mém. Poudres*, No. 35, 1953, pp. 233–272.) *Gt. Brit., MOS T1L/T4836*, Aug., 1959. 39 pp. Translation. Calculation of the energy characteristics of propellants. The gases produced by the decomposition of propellants are examined, and formulas are derived, indicating the nature and volume of the gases involved.

On the Testing of Explosive Substances. IV—Determining the Sensitivity to Impact of Explosive Materials of Solid, Fluid and Gelatinous Nature. H. Koenen, K. H. Ide, and W. Haupt. (*Explosivstoffe*, No. 8, 1958, pp. 178–189.) *Gt. Brit., MA T1L/T4981*, Dec., 1959. 16 pp. Translation.

Gliders

Několik Zkušeností z Hledání Nových Metod Měření Poláry Větroně. Vlastimil Pokorný. *Zpravodaj VZLÚ*, Nov.-Dec., 1958, pp. 59–64. In Czechoslovak. Presentation of a preliminary analysis and experimental results on two methods used for measuring the glider lift-drag curve.

Instruments

Flight Instruments

Flight Test of the "Safe Flight Landing Speed Indicator." W. G. A. Port and D. Lean. *Gt. Brit., RAE TN Aero. 2618*, Apr., 1959. 11 pp. Description of flight tests on a twin-jet straight wing aircraft, indicating the advantages of the device due to the automatic compensation for the changes in aircraft weight and continuously indicated margin between actual incidence and stalling incidence during approach maneuvers.

Man-Made Mirage. J. F. Scheer. *Skyline*, No. 1, 1960, pp. 40–45. Presentation of the basic principles and various applications of a pilot's display projector which simulates images of the horizon, the outline of obstacles, or the earth below and projects them into the pilot's forward view in proper perspective.

Radiový Výškoměr. Antonín Wild. *Zpravodaj VZLÚ*, Jan., 1959, pp. 27–30. In Czechoslovak. Discussion of the important features of frequency-modulated radio-altimeters.

The New Dial Gauge Acting on the Principle of the Air Micrometer. Shin'ichiro Takeda. *Hosei U. Tech. Coll. Rep. 5*, Nov., 1959. 20 pp. Description of an accurate instrument having a wide measuring range with a very small measuring pressure that makes special calibration unnecessary. The instrument is suited for the measurement of the pressure-displacement characteristics of diaphragms for aircraft instruments.

Flow Measuring Devices

Discharge Measurement in Circular Pipes Using Current Meters. M. Blahó. *Periodica Polytech., Eng. Ser.*, No. 2, 1958, pp. 77–82. Presentation of an area-velocity method using ten points along two diameters which are perpendicular to each other.

Přístroj pro Měření Síly a Směru Větru. Jiří Tůma. *Zpravodaj VZLÚ*, July-Aug., 1958, pp. 46, 47. In Czechoslovak. Description of a recording anemometer, covering its method of operation and design.

Měření Charakteristik Proudícího Prostředí při Nízkých Rychlostech Sondami na Měření Tlaku. Vlastimil Krýzl. *Zpravodaj VZLÚ*, July-Aug., 1958, pp. 16–21. In Czechoslovak. Evaluation of factors involved in the measurement of low-speed flows by means of various pressure indicating devices. Included are such types as the pitot-static tube, the cylindrical total-head tube, and the integrating total-head tube.

A Note on Fluctuating Heat Transfer at Small Péclet Numbers. C. R. Illingworth. *J. Fluid Mech.*, Mar., 1960, pp. 442–448. Presentation of solutions for the temperature field when a warm circular cylinder or a warm sphere is held at rest in a fluctuating stream. Applications to the hot-wire anemometer are emphasized.

Gyroscopes

Cryogenic Gyros with Super Accuracy. *Electronic Des.*, Mar. 2, 1960, pp. 4–7. Presentation of the efforts in creating gyros so refined that the drift rate is all but eliminated. The planned gyros will operate at cryogenic temperatures and in the superconductive state. Progress thus far achieved and problems yet to be solved are pointed out.

The Stability of Motion of a Gyroscope. Chzhan Sy-In. (*Prikl. Mat. i Mekh.*, May-June, 1959, pp. 604, 605.) *PMM—Appl. Math. & Mech.*, No. 3, 1959, pp. 860–863. Translation. Derivation of the necessary stability conditions for a symmetrical gyroscope in the case of a horizontal external ring axis.

Stress & Strain Measuring Devices

Měření Deformací a Napětí Odporovými Tensometry. Oldřich Kropáč. *Zpravodaj VZLÚ*, Nov.-Dec., 1958, pp. 3–14. 15 refs. In Czechoslovak. Survey of possible applications of resistance strain gages for the measurement of strains and stresses. The effect of transverse sensitivity is studied and formulas for the determination of true strains from strain-gage readings are given. Different methods of measurement in the regions of especially small or especially large deformations are studied.

Temperature Measuring Devices

Notes on a Thermal Fluxmeter. Appendix—**The Influence of a Transfer Resistance Between the Plate of the Fluxmeter and the Cooling Water on the Time-Constant of the Instrument.** J. Plenier. (*Etabliss. Aéro. Toulouse Rep.*, May 29, 1958.) *Gt. Brit., RAE Lib. Transl. 843*, Oct., 1959. 45 pp. Discussion of the theory, construction, calibration, performance, and possible improvements of an instrument for measuring the thermal flux generated by infrared radiant heating installations.

Development of a Thin Film Heat-Transfer Gauge for Shock-Tube Flows. B. W. Taylor. *UTIA TN 27*, June, 1959. 34 pp. 13 refs. Investigation of the use of liquid platinum paint for the manufacture of thin film resistance thermometers. Films so made are used for the measurement of heat transfer rates in the UTIA 2 × 2 in. strong shock tube. Theoretical considerations are included.

Vibration Measuring Devices

Měření Mechanických Kmitů Relativními Snímači. Ivo Středa. *Zpravodaj VZLÚ*, Nov.-Dec., 1958, pp. 69–72. In Czechoslovak. Presentation of basic data on the measurement of mechanical vibrations by means of relative pickups. A classification of pickups and the limitations in their applications, as well as essential data on a Czech vibration pickup, and description of a newly developed relative pickup are included.

Příspěvek k Problému Měření Vibrací Absolutními Snímači. Ivo Středa. *Zpravodaj VZLÚ*, Jan., 1959, pp. 31–36. 10 refs. In Czechoslovak. Survey of basic relations and data in the field of mechanical vibration measurement. Basic equations describing the behavior of pickups are presented, and various methods of electrical measurement are indicated.

Lighter-than-Air

Development and Test of a Balloon-Borne Manned Vehicle. R. L. Geer and J. F. Rayfield. *USAF WADC TR 59-226*, June, 1959. 42 pp. Discussion of the design, fabrication, and testing of a balloon-borne vehicle. Included are presentations of new designs for a pressure-retaining hatch and an energy-absorbing parachute landing device.

Machine Elements

Bearings

The Development and Testing of High Temperature Bearings. R. T. Westmoreland and P. J. Hanifin. *SAE Natl. Aero. Meeting, Los Angeles, Oct. 5–9, 1959, Preprint 112U.* 10 pp.

Refinements of the Theory of the Infinitely-Long, Self-Acting, Gas-Lubricated Journal Bearing. H. G. Elrod, Jr., and Albert Burgdorfer. (*1st Internatl. Symposium Gas Lubricated Bearings, Wash., Oct. 26–28, 1959.*) *Franklin Inst. Labs. Interim Rep. I-A2049-10*, Jan., 1960. 43 pp. ONR-supported research.

Determination and Correlation of Fundamental Instrument Bearing Parameters. T. P. Barnard and R. S. Guyette. *Lubrication Eng.*, Feb., 1960, pp. 61–68. Evaluation of dimensional, geometrical, and performance characteristics of miniature instrument ball bearings. The instrumentation used to accomplish the required measurements, and the development of a bearing quality analyzer are described. The use, correlation, and interpretation of these instruments and test data are illustrated by actual test results.

Fastenings

Self-Locking Nuts in Aero Engineering. W. H. Seidel. (*Luftfahrttechnik*, July 15, 1959, pp. 255, 256.) *Gt. Brit., MA T1L/T5091*, Jan., 1960. 3 pp. Translation.

Gears & Cams

Torque Distribution, Power Flow and Zero Output Conditions of Epicyclic Gear Trains. Bengt Jakobsson. *Chalmers Tek. Högskolas Handlingar, No. 224*, 1960. 55 pp.

Rotating Discs & Shafts

Der Einfluss der Werkstoffdämpfung auf die Bewegung und Stabilität der Rotoren. Aleš Tondl. *Acta Technica*, No. 3, 1959, ppl 208–217. In German. Theoretical analysis of the effect of nonlinear friction on the motion and stability of rotors. The problem is solved for the case of a horizontal as well as a vertical shaft. The study is limited to the stability of steady vibrations, assuming constant frequency of rotation of the shaft.

Seals

Evaluation of Designs and Materials for High Speed–High Temperature Shaft Seals for Turbojet Engine Applications. J. J. Brenza, J. H. Fuchsluger, G. F. Hyde, and E. J. Taschenberg. *USAF WADC TR 56-267, Pt. II*, Dec. 31, 1958. 88 pp.

Leakage and Wear in Mechanical Seals. Ehrhard Mayer. *Mach. Des.*, Mar. 3, 1960, pp. 106–113. Presentation of results of tests on unbalanced seals using five face material combinations and three different fluids. The factors causing leakage and wear in mechanical seals, leakage calculation, and techniques for reducing leakage and wear are discussed.

Materials

Research on the Pyrolytic Deposition of Thin Films. F. V. Schossberger, S. Spriggs, P. Ticulka, E. Tompkins, and E. Fagen. *USAF WADC TR 59-363*, Oct., 1959. 42 pp. 14 refs. Discussion of methods for the preparation, chiefly by pyrolytic deposition, of thin films potentially useful in composite molecular electronics, especially films with high temperature stability. The limits of composition, the conditions of firing, and the optimum thickness required for a flexible alloy layer are determined. Beta-ray backscattering is shown to be a useful method for the measurement of film thickness.

Ceramics & Ceramals

Ceramic Studies Summary Technical Report. P. Gibbs, G. S. Baker, E. K. Beauchamp, and M. H. Miles. *USAF WADC TR 59-381*, Aug., 1959. 13 pp.

Development and Evaluation of Insulating Type Ceramic Coatings. E. W. Blocker, C. A. Hauck, S. Sklarew, and A. V. Levy. *USAF WADC TR 59-102*, Nov., 1959. 64 pp.

Rolling-Contact Fatigue Life of a Crystallized Glass Ceramic. Appendix A—**Stress Cycle Relation.** Appendix B—**Derivation of Maximum Compressive Hertz Stress as a Function of Young's Modulus of Elasticity for Two Spheres in Contact.** T. L. Carter and E. V. Zaretsky. *U.S., NASA TN D-259*, Mar., 1960. 35 pp.

Metal Fiber Reinforced Ceramics. J. J. Swica, W. T. Hoskyns, B. R. Goss, J. H. Connor, and J. R. Tinklepaugh. *USAF WADC TR 58-452, Pt. II*, Jan., 1960. 41 pp. Evaluation of the principal geometric variables involved in

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ACOUSTICS, SOUND, NOISE

THE OSCILLATION AND NOISE OF AN OVER-PRESSURE SONIC JET. A. G. Hammitt. GASL TR 137 (AFOSR TN 59-1307), Nov., 1959. 35 pp. Discussion of a series of experiments on plane two-dimensional and axially symmetric over pressure sonic jets, performed to study the oscillating behavior of the jet and accompanying sound field. Shadowgraphs were obtained which show the oscillations and generation of the sound waves for the plane two-dimensional jet in some detail; but similar results could not be obtained for the axially symmetric jet. Measurements from these pictures show that the oscillating jet and sound fields can be described in terms of the length of the shock wave cells. The importance of the sound waves acting upon the base of the jet is demonstrated and it is found that the jet can be stabilized by shielding its base from these sound waves.

THE SUPERSONIC BOOM OF A PROJECTILE RELATED TO DRAG AND VOLUME. I. L. Ryhming. Boeing Sci. Res. Lab. FSL Rep. 15, D1-82-0023, Oct., 1959. 30 pp. Application of the Whitham theory predicting the far flow field around a projectile to derive body shapes which produce extreme bow shock wave pressure jump or "boom," subject to constraining conditions regarding the drag due to the bow shock and fineness ratio of the bodies. It is found that the minimum drag body is also the minimum boom body. The body volume effect and the effect of discontinuities in slope of the body meridian section on the boom intensity is investigated. As a general result of the investigation, it is shown that the boom of a projectile for given Mach number and flight altitude is primarily determined by its length and fineness ratio. The maximum variation in the boom intensity for pointed bodies with given length and fineness ratio is of the order of 10%. The geometry of the bodies is thus found to play a minor role.

GROUND MEASUREMENTS OF AIRPLANE SHOCK-WAVE NOISE AT MACH NUMBERS TO 2.0 AND AT ALTITUDES TO 60,000 FEET. L. J. Lina and D. J. Maglieri. US, NASA TN D-235, Mar., 1960. 25 pp. Presentation of ground-based measurements of sonic-boom intensities. Effects of altitude, flight-path angle, Mach number, and atmospheric refraction at the cutoff Mach number are investigated. The effects of aircraft size and weight are determined by comparison of measurements made from one flight of a supersonic bomber with data for the supersonic fighter which is used for most of the tests.

AERODYNAMICS, FLUID MECHANICS

Aerothermochemistry, Dissociation, Ablation

TRANSPORT AND THERMODYNAMIC PROPERTIES IN A HYPERSONIC LAMINAR BOUNDARY LAYER. II - APPLICATIONS. S. M. Scala and Ch. W. Baulknight. ARS J., Apr., 1960, pp. 329-336. 17 refs. Analysis in which the transport and thermodynamic properties of dissociated air, presented previously, and the Curtiss, Hirschfelder, and Bird method of predicting the thermal conductivity of a chemically reacting gas, are utilized to determine the stagnation point heat transfer to a hypersonic vehicle. New theoretical results are obtained and compared with earlier theoretical results, and with available experimental data. It is found that at both high and low altitudes the results are larger than the values predicted by Sibulkin and by Lees, but smaller than those of Romig, and Fay and Riddell. It is also found that the results are consistently lower than the mean value of the shock tube data of Rose and Stark, and Vitale.

EXPERIMENTS ON THE DEPARTURE FROM CHEMICAL EQUILIBRIUM IN A SUPERSONIC FLOW. P. P. Wegener. (ARS Semi-Annual Meeting, San Diego, June 8-12, 1959.) ARS J., Apr., 1960, pp. 322-329. 16 refs. USAF-Army-sponsored theoretical and experimental investigation of stationary supersonic nozzle flow of a reacting gas mixture in thermodynamic equilibrium or in states between equilibrium and frozen flow. Using this

fully determined flow system, various criteria to predict departures from equilibrium were examined. A method proposed by Bray for Lighthill's ideal dissociating gas was extended to the real gas system, and the results showed agreement with the experiments.

ON CHEMICAL REACTIONS IN INTERNAL FLOW SYSTEMS. P. L. Chambré. Appl. Sci. Res., Sect. A, No. 2-3, 1960, pp. 157-168. ONR-supported development of a general analytic method with which the specie concentrations and temperature for mildly nonisothermal systems can be determined. The basic equations are presented for a homogeneous reaction in an internal flow system with a fully established velocity field. It is shown that the specie concentrations can be found from a single function -- i.e., the degree of advancement of the reaction - while the temperature is determined through a generalized enthalpy function which takes into account the thermal exchange with the exterior. Under the mildly nonisothermal conditions, the determination of the two basic functions reduces to the solution of two linear parabolic equations and their associated Sturn-Liouville systems.

THE LINEARIZED FLOW OF A DISSOCIATING GAS. J. F. Clarke. J. Fluid Mech., Apr., 1960, pp. 577-595. 10 refs. Presentation of the linearization of the equations for planar two-dimensional steady flow of an ideal dissociating gas, assuming small disturbances to a free stream in chemical equilibrium. As an example of their solution, the flow past a sharp corner in a supersonic stream is evaluated and the variations of flow properties in the relaxation zone are found. Numerical illustrations are provided using an "oxygen-like" ideal gas and comparisons are made with a characteristics solution.

THE TWO-DIMENSIONAL FLOW OF AN IDEAL DISSOCIATING GAS. J. W. Cleaver. Coll. of Aeronautics, Cranfield, Rep. 123, Dec., 1959. 24 pp. 16 refs. Discussion of the ideal oxygen-like gas introduced by Lighthill. The rate equation is given and then the partial differential equations governing the motion of this ideal gas are treated by a standard characteristic method. Due to the entropy production associated with the chemical reactions, analytical solutions are not possible, and a numerical step-by-step method is used to obtain a solution. As an application of the method developed, the flow field around a sharp corner of an ideal dissociating gas is examined. It is found that the relaxation zones were considerably influenced by the free stream conditions; for the small expansion angles considered the flow will be rapidly adjusted to new equilibrium conditions.

THE EFFECT OF DISSOCIATION AND RECOMBINATION OF OXYGEN AND NITROGEN ON THE HEAT TRANSFER TO A BODY FLYING IN A RAREFIED ATMOSPHERE. J. A. Wilson. U. Southampton Dept. Aeron. & Astron. Rep. 113, Jan., 1960. 40 pp. Analysis in which a certain percentage of the incident molecules are assumed to dissociate upon coming into contact with a body, and an allowance is also made for possible recombination of free atoms on the body surface. An energy balance is then formulated and the effect on the heat transfer rate and body temperature is studied for various amounts of dissociation. The orders of magnitude of the various sources of energy are compared with each other in order to establish whether any one of them is negligible compared with the others under all conditions. The particular case of a circular cylinder is considered, and curves are plotted to show the relative magnitude of the various terms in the heat transfer equation. It is shown that the heat transfer rate for the case of completely dissociated air in a high-enthalpy, low-density wind-tunnel is greater than that for a body flying at the same velocity in partially dissociated air at high altitude.

ON THE DRAG OF A SPHERICAL SATELLITE MOVING IN A PARTIALLY IONIZED ATMOSPHERE. H. H. C. Chang and M. C. Smith. Brit. Interpl. Soc. J., Jan.-Feb., 1960, pp. 199-205. 12 refs. Analysis that assumes the temperatures of electrons and positive ions to be approximately equal. For most satellites it follows that the satellite sweeps out ions and neutral particles only along its direction of motion but is bombarded from all directions by electrons. The charge or the potential of the satellite is determined for two different cases by the boundary condition that requires at equilibrium the total current to the satellite to be zero. Competitive processes which would charge the satellite oppositely are discussed and used to determine the potential of the satellite. "Distant" collisions are discussed briefly and their importance is estimated.

HEAT TRANSFER FROM DISSOCIATED GASES IN A SHOCK TUBE. R. A. Hartunian and P. V. Marrone. Cornell Aero. Lab. Rep. AD-1118-A-7 (AFOSR TN 59-1087), Nov., 1959. 72 pp. 38 refs. Description of measurements of the heat transfer from dissociated oxygen to the side wall of a shock tube made over a wide range of operating conditions using the methods of thin-film thermometry. Numerical solutions of the equilibrium shock-tube wall boundary-layer equations for several values of the Lewis number have been obtained. The results show the heat transfer to be weakly dependent upon the Lewis number. Experimental data obtained in the equilibrium boundary-layer regime agree with the theory at low temperatures, and rise above the theoretical curves at higher temperatures. This difference between theory and experiment is attributed to the uncertainty in the calculated viscosity coefficient used in the theory. The experiments were then used to determine new values for the viscosity coefficient of high temperature, dissociated oxygen. These values are considerably higher than those predicted theoretically using a Lennard-Jones potential or Sutherland's formula.

THE CALCULATION OF HEAT FLOW IN MELTING SOLIDS. Mark Lotkin. Quart. Appl. Math., Apr., 1960, pp. 79-85. Extension of a

previous study on the numerical integration of certain heat conduction equations to include the phenomenon of melting. In carrying out this extension, it is found advisable to use unequal subdivisions in both space and time variables. Near the melting surface, where the changes of temperature may be very pronounced, it is advantageous to choose rather small integration steps. Farther away from the melting surface, where the temperature may change rather slowly, a more economic treatment of the integration process may be achieved by taking relatively large intervals in the independent variables. In the analysis, the physical situation is first defined and the governing mathematical equations are stated. These differential equations are next replaced by analogous difference equations, and the resulting truncation terms are noted. It is found that the stability characteristics of the method are quite similar to those established in the original study.

ABLATION STUDIES OF LOW MELTING POINT BODIES IN A PRE-HEATED SUPERSONIC AIR STREAM. Appendix A - SIMPLIFIED ANALYSIS OF MELTING FOR WHICH $(T_w)_o \simeq T_m$. Appendix B - ABLATION OF CONES AND HEMISPHERES FOR WHICH $(T_w)_o \simeq T_m$. J. W. Cleaver and F. Thomson. Coll. of Aeronautics, Cranfield, Rep. 127, Feb., 1960. 29 pp. Investigation of the melting of axisymmetric and two-dimensional bodies at a Mach number of 1.78 and stagnation temperatures up to 550°K. In this temperature range, the most suitable material for the models was found to be an eutectic tin-lead alloy with a melting point of 456°K. For the cone and hemisphere-cone models, two distinct modes of melting were observed. In cases where the estimated equilibrium surface temperature $(T_w)_o$ was approximately equal to the material melting temperature T_m, melting occurred only at the stagnation point of the model and was such that a flat surface normal to the gas stream always resulted. For $(T_w)_o > T_m$, the stable shape had a paraboloidal nature. For $(T_w)_o \simeq T_m$, the rates of heat transfer were found to decrease with increase of the radius of the flat ablating surface. For $(T_w)_o > T_m$, it was found that the rate of recession of the stagnation point usually reached a constant value and the shape of melting was then steady. Under these steady conditions heat transfer rates were evaluated.

TRANSIENT TEMPERATURES AND THERMAL VIBRATIONS IN SPACE STRUCTURES. Luigi Broglio. Roma U. Sch. Aero. Eng. Inst. Aero. Construc. Rep. SIAR 53 (AFOSR TN 59-1014), June, 1959. 66 pp. Solution of the heat conduction problem and of the static and dynamic thermal stresses by solving two different eigenproblems: the problem of the natural frequencies and normal modes of vibration of an ideal body whose elasticity and mass are related to the thermal coefficients of the body, and the problem of the actual frequencies and modes of vibration of the real body. The general solution of each of the two problems is reached when Green's function is determined. These results are then applied to ablation of a hollow sphere for two cases: conductive material and material with zero conductivity. Finally, the following numerical examples are given: (1) temperature distribution in a re-entering hemisphere considering five different types of materials, (b) thermoelastic displacements due to a step heat source in an infinite solid, and (c) ablation in a conducting sphere.

A SIMPLIFIED STUDY ON THE NONEQUILIBRIUM COUETTE AND BOUNDARY-LAYER FLOWS WITH AIR INJECTION. P. M. Chung. US, NASA TN D-306, Feb., 1960. 69 pp. 22 refs. Analysis considering the simultaneous effect of the finite recombination rate of oxygen atoms and the fluid injection on the heat transfer to a flat surface. Couette flow and Rayleigh's analogy for laminar boundary-layer flow are studied. All the fluid properties except temperature and composition are considered to be constant and a special linear approximation of the homogeneous reaction rate law is also made.

AN ELEMENTARY STUDY OF GAS INJECTION AND SUBLIMATION INTO A SIMPLE SHEAR LAYER. J. F. Clarke. Coll. of Aeronautics, Cranfield, Rep. 126, Feb., 1960. 18 pp. Study of the injection of a foreign gas into a simple shear layer (Couette flow) and extension of results to the case for which the wall material sublimes under the action of heat transferred through the layer. Homogeneous chemical reactions are not considered, and the variations of sublimation temperature with pressure are examined briefly by means of the kinetic theory.

Aerothermodynamics

ANISOTROPIC COMPOSITE THERMAL STRUCTURES FOR HYPERSONIC FLIGHT. Luigi Broglio. Roma U. Sch. Aero. Eng. Inst. Aero. Construc. Rep. SIAR 52 (AFOSR TN 59-1015), Feb., 1959. 43 pp. Presentation of fundamental solutions for the temperature distribution and thermoelastic motion produced by an instantaneous heat source located at an arbitrary point in an anisotropic heterogeneous composite body of arbitrary shape. Application of the results is made to composite and anisotropic structures. Numerical examples show the possibility of a substantial decrease of maximum temperature at the outer surface and a substantial increase of insulation at the inner surface even by using simpler designs, such as a two-component composite or an anisotropic hemisphere whose lateral thermal conductivity is nearly three times greater than the normal one.

AN EXACT SOLUTION TO A PROBLEM IN KINETIC HEATING. C. H. J. Johnson. Australia, ARL Mech. Eng. Note 236, Aug., 1959. 6 pp. Presentation of an exact solution to the problem of determining the temperature distribution in a heat conducting half-space subsequent to the impulsive motion in a direction parallel to the surface of a constant property fluid lying over it.

Boundary Layer

THE ESTIMATION OF LAMINAR SKIN FRICTION, INCLUDING THE EFFECTS OF DISTRIB-

UTED SUCTION. N. Curle. Aero. Quart., Feb., Pt. I, 1960, pp. 1-21. 17 refs. Development of a generalization of Stratford's theory for retarded flow to yield accurate predictions of separation and detailed distribution of skin friction. Three distinct types of examples are presented, the solutions in each case being compared with exact solutions or with accurate solutions by other approximate methods. First, flows without suction are considered, and then problems with prescribed suction and pressure gradient. Finally, the method is applied to flows with zero pressure gradient and prescribed suction.

BOUNDARY LAYERS OVER INFINITE YAWED WINGS. J. C. Cooke. Gt. Brit., RAE TN Aero. 2663, Dec., 1959. 17 pp. 10 refs. Presentation of a method for calculating turbulent boundary layers on infinite yawed wings, making use of a method of calculating turbulent boundary layers due to Spence and an analogy between three-dimensional and axisymmetric boundary layers. It is also shown that the displacement thickness is equal to that computed using chordwise components and that the streamwise momentum thickness is approximately equal to the chordwise momentum thickness. Shock free flow, small boundary layer cross flow, and zero heat transfer are assumed.

ON SIMILAR SOLUTIONS OF THE STEADY QUASI-TWO-DIMENSIONAL INCOMPRESSIBLE LAMINAR BOUNDARY-LAYER EQUATIONS. Nisiki Hayasi. Phys. Soc. Japan J., Mar., 1960, pp. 522-527. 15 refs. Development of three-dimensional incompressible laminar boundary-layer equations using orthogonal curvilinear coordinates. These equations reduce to a two-dimensional type if one component of the velocity and the pressure gradient in that direction are negligible throughout the boundary layer. Conditions for the existence of similar solutions for such quasi-two-dimensional boundary layer are investigated, and new similar solutions are found using "planar coordinates" α , β , γ (γ =0 giving the surface).

PRELIMINARY EXPERIMENTAL INVESTIGATION OF EFFECT OF FREE-STREAM TURBULENCE ON TURBULENT BOUNDARY-LAYER GROWTH. S. J. Kline, A. V. Lisin, and B. A. Waitman. US, NASA TN D-368, Mar., 1960. 60 pp. 17 refs. Evaluation of preliminary test results showing that the normally employed correlations for the turbulent boundary layer on a plate are, in effect, a limiting law for low turbulence in the free stream. However, when the free-stream turbulence is equal to, or greater than, the self-generated turbulence of the shear layer, considerable alterations in the boundary-layer characteristics occur. Such altered boundary layers do not conform to the "universal" velocity profiles in the form of the law of the wall or the law of the wake. A straight-line portion of the layer on a semilogarithmic plot still exists, but its slope and location are altered and are shown to depend upon the imposed free-stream fluctuation intensity.

Flow of Fluids

ON THE SUDDEN CONTACT BETWEEN A HOT GAS AND A COLD SOLID. J. F. Clarke. Coll. of Aeronautics, Cranfield, Rep. 124, Jan., 1960. 34 pp. Study of the flow induced by the sudden contact between a semi-infinite expanse of gas and a solid, initially at different temperatures, considered on the basis of linear continuum theory. For times large compared with the mean time between molecular collisions in the gas, the velocity and pressure disturbances are found to be concentrated around a wave front propagating out from the interface at the ambient isentropic sound speed; whereas, near the interface, these disturbances are small and the gas temperatures are nearly equal to those predicted by the classical constant pressure heat conduction theory. The possible significance of these results in connection with reflected shock wave techniques to measure high temperature gas properties is commented upon.

THEORETICAL PREDICTION OF PRESSURES IN HYPERSONIC FLOW; CONFIGURATIONS WITH ATTACHED LEADING EDGE SHOCK. R. A. Scheuing, J. W. Brook, R. E. Melnik, H. R. Mead, W. D. Hayes, and K. E. Gray. Grumman Aircraft Eng. Corp. Res. Dept. Res. Rep. RE-124, Nov., 1959. 90 pp. 34 refs. USAF-supported study undertaken to develop theories for predicting pressures in hypersonic flows, with emphasis on inviscid hypersonic flow around configurations which have attached leading-edge shock waves. Improvement is achieved in the shock-expansion theory to apply to hypersonic flows where reflections of expansions from shocks and vorticity layers become important. A qualitative discussion is given of the physical and mathematical characteristics of conical flows. The thin shock layer theory is extended to arbitrary, but smooth, conical configuration shapes. Finally, a procedure is given for numerical solution of flow over a flat-plate delta wing using approximate nonlinear conical flow theory.

SHOCK WAVE - BOUNDARY LAYER INTERACTION AND LEADING EDGE SLIP IN A FLAT PLATE IN HYPERSONIC FLOW. H. T. Nagamatsu and R. E. Sheer, Jr. ARS Semi-Annual Meeting, San Diego, June 8-11, 1959, Preprint 855-59. 40 pp. 28 refs. USAF-sponsored investigation conducted over a Mach number range from 9.77 to 19.6 with a reflected stagnation temperature of 2,500°R., and at a flow Mach number of 7.8 with the stagnation temperature of 7,200°R. Slip flow effects at the sharp leading edge were observed; the strong shock wave and the boundary layer were delayed in forming on the plate. The slip region increased with the free-stream flow Mach number and with the mean free path of the air ahead of the model. In the strong interaction region near the leading edge, the viscous region extended from the plate surface to the shock wave and there was no apparent inviscid region between the shock wave and the boundary layer. The induced pressure on the plate varied inversely as the

square root of the distance from the leading edge as was originally predicted theoretically by Li and Nagamatsu. Cooling of the boundary layer by the plate surface had a large effect upon the magnitude of the induced pressure at high flow Mach numbers. Even for a reflected stagnation temperature of 7,200°R., with appreciable real gas effects, the strong interaction between the shock wave and the boundary layer was present.

SUPERPOSABILITY IN MAGNETOHYDRODYNAMICS. II. J. N. Kapur. Appl. Sci. Res., Sect. A, No. 2-3, 1960, pp. 139-147. 16 refs. Application of previously derived equations of motion for axially symmetric viscous hydromagnetic flow to the following cases: (a) superposability of wave motions, (b) hydrostatic equilibrium of magnetic stars, (c) effects of viscosity in axially symmetric hydromagnetic flows, (d) axially symmetric force-free fields, and (e) general force-free fields.

TRAILS OF AXI-SYMMETRIC HYPERSONIC BLUNT BODIES FLYING THROUGH THE ATMOSPHERE. Appendix - CALCULATION OF THE LENGTH OF THE FROZEN WAKE. Saul Feldman. Avco Everett Res. Lab. RR 82, Dec., 1959. 92 pp. 11 refs. Army-sponsored study of observable effects of hypersonic trails – i.e., the emitted thermal radiation and reflection of electromagnetic waves from the trails. For the purpose of analysis the trail is divided into two regions: (1) the expansion-controlled trail, which treats the behavior of the wake behind the body up to a point, along the direction of flight, where the pressure decays to the free stream value and cooling is principally controlled by the expansion of the flow; and (2) the conduction-controlled trail, where the trail cools mainly by diffusion of heat away from the high temperature core. The influence of the body shape on the observables is discussed and a simple computational procedure for the behavior of the conduction-controlled trail is developed on the basis of integral methods. Results of calculations that assume thermodynamic equilibrium of the flow field give the values of the thermodynamic variables in the trail of a sphere, axial distributions of emitted thermal radiation, and maps of electron density distribution. It is shown that viscous effects in blunt body trails are of small importance and that the cooling of the conduction-controlled trail is essentially due to heat conduction.

ON CERTAIN PROPERTIES OF HYDROMAGNETIC SHOCKS. W. B. Ericson and Jack Bazer. (Am. Phys. Soc. Symposium Plasma Phys., Monterey, Dec. 4, 1959.) Grumman Aircraft Eng. Corp. Res. Dept. Res. Rep. RE-128, Nov., 1959. 41 pp. Presentation of proofs for the four basic properties of stationary, planar, nonrelativistic hydromagnetic shocks that had been developed previously. These are the following: (P_1) the specific entropy behind a hydromagnetic shock exceeds that ahead, if and only if, the shock is compressive; (P_2) the specific entropy behind a compressive shock varies in the same sense as the mass flux; (P_3) in the region behind (compressive) fast shocks, the fast disturbance speed is greater than the normally-directed fluid velocity relative to the shock; (P_4) in the region behind (compressive) slow shocks, the slow disturbance speed may be less than, equal to, or greater than the normally-directed fluid velocity relative to the shock. The equality holds when the specific entropy and the mass flux assume their maximum values.

SOME ENGINEERING ASPECTS OF THE MAGNETOHYDRODYNAMIC PINCH PROCESS FOR SPACE PROPULSION. Irving Granet and W. J. Guman. Republic Av. PPL Rep. 120 (AFOSR TN 60-86), Nov., 1959. 41 pp. 16 refs. Description of the several analytical models currently in use to describe the pinch process, and discussion of approximations contained in each and of their limitations. The "snow-plow" method was selected for the analysis of a propulsion system with various combinations of the input parameters. The coupled governing differential equations are given and the results of a computer program are analyzed. Based upon momentum considerations, a generalized correlation is proposed and tested against the calculations and available experimental data.

GETTI DI FLUIDI ELETTRICAMENTE CONDUTTIVI IN PRESENZA DI CAMPI MAGNETICI. A. Pozzi. (AIR 1st Natl. Congr., Genoa, Oct. 5-12, 1959.) Missili, Dec., 1959, pp. 27-38. 13 refs. In Italian. Investigation of the effects of a magnetic field on a jet of electrically conducting fluid discharging into a fluid at rest. The study is made for the case of dissipative flow in the absence of solid boundaries. The pertinent basic equations are derived, and their solutions are presented and discussed for the case of plane and circular jets.

ON THE SOLUTION OF THE HODOGRAPH EQUATION FOR THE SHOCK WAVE IN LOCALLY SUPERSONIC ZONE. Shun-i-chi Tsuge. (T. Moriya Memorial Seminar for Aerodynamics.) U. Tokyo Fac. Eng. Dept. Aero. Res. Memo. 2, Dec., 1959. 20 pp. Study of a boundary value problem for Tricomi's equation, associated with two-dimensional high subsonic flow in a partially supersonic zone. The shape of the shock is expressed by an integral-differential equation. Though it cannot be completely solved due to its complexity, the main features of the shape of the shock wave are determined from a study of the critical point of an ordinary differential equation derived from generalized spine relations. The generalized Busemann's spine relations, being transformed back to the physical plane, furnish a new pattern of flow past an airfoil in which the sonic line starting from an obstacle runs around the shock wave and touches it from behind.

CURVATURE OF ATTACHED SHOCK WAVES IN STEADY AXIALLY SYMMETRIC FLOW. E. Bianco, H. Cabannes, and J. Kuntzmann. J. Fluid Mech., Apr., 1960, pp. 610-616. Calculation of the ratio between the initial radii of curvature of the attached shock wave and the body for

an axially symmetrical body in a uniform supersonic stream. An electronic computer has been used for the calculation, and the results are obtained to four exact digits for more than 200 cases.

ON SOME UNSTEADY FREE MOLECULAR SOLUTIONS TO THE BOLTZMANN EQUATION. Appendix - EXACT CALCULATION OF THE DENSITY VARIATIONS ALONG THE CENTERLINE OF THE REGION BEHIND A SPHERE MOVING THROUGH A RAREFIED GAS. E. Kornowski. G-E MSVD SSL TIS R59SD463, Nov., 1959. 19 pp. USAF-supported development of solutions for the filling of regions whose configurations are a channel, cylinder, and sphere, and presentation of density profiles as a function of time and space. The density profiles obtained for the filling of the cylinder are applied toward obtaining the density profiles aft of a sphere moving through a rarefied gas. It is shown that these profiles are accurate for the region which is greater than three radii behind the sphere center, and that the velocity of the sphere must be at least three times the most probable velocity of the gas particles.

SIMILARITY STRUCTURE OF VORTICITY FLUCTUATION AND THE THEORY OF TURBULENCE. Chou Pei-Yuan. Scientia Sinica, Oct., 1959, pp. 1095-1119. 34 refs. Development of a theory of turbulence based upon the random motion of vortices having specific characteristics. It is deduced that since the turbulent mean velocity distribution obeys the condition of similarity in the field of flow, the random motion of vortices of which the turbulent fluctuation is composed, should also have a similarity structure. The equations of turbulent velocity fluctuation are derived from the Navier-Stokes equations and mean motion equations. Similarity solutions for the turbulent vorticity equations are then obtained from the turbulent velocity equations, and explicit relations are established between the components of the Reynolds stress and the spatial derivatives of the mean velocity of the turbulent flow. Examples are given for flows within a two-dimensional channel, along a semi-infinite plate, through a circular pipe, and in the two-dimensional and axially symmetric wakes. The examples show that different kinds of flow conditions produce two different types of vortices. The relation between the scale of vorticity Λ and the microscale of turbulence λ, which is defined by the two-dimensional velocity correlation, is constructed out of solutions of the nonlinear equations of vorticity fluctuation after performing the similarity transformations.

REMARKS ON TRANSITION IN A ROUND TUBE. A. M. O. Smith. J. Fluid Mech., Apr., 1960, pp. 565-576. 16 refs. Presentation of the available theoretical and experimental knowledge concerning flow in the inlet region of a smooth round tube. It is pointed out that the e^9 amplification factor method apparently predicts natural transition correctly over a significant fraction of the entire inlet length of the tube. The successful prediction indicates, but does not prove, that flow in a smooth round tube becomes turbulent at higher Reynolds numbers because transition occurs in the inlet length and not in the fully developed Poiseuille régime.

Internal Flow

THE AERODYNAMIC DERIVATIVES OF AN AEROFOIL OSCILLATING IN AN INFINITE STAGGERED CASCADE. A. H. Craven. Coll. of Aeronautics, Cranfield, Rep. 125, Jan., 1960. 17 pp. Application of thin airfoil theory to extend the work of Mendelson and Carroll in order to include arbitrary stagger angle and phase difference between adjacent blades. An integral equation relating local velocity and vorticity is solved and the aerodynamic derivatives are found in integral form. The expressions obtained reduce, for zero stagger and for in-phase and antiphase oscillations, to known results.

SUPERSONIC INLET DYNAMICS. Appendix - DERIVATION OF THE TRANSFER FUNCTION FOR A SUPERSONIC INLET DUCT. H. R. Fraiser. J. Aero/Space Sci., June, 1960, pp. 429-436. Presentation of an approximation of the differential equation for compressible duct flow which is linear and of the second order. The duct transfer function and response characteristics are obtained by applying small-perturbation theory to the differential equation. The resulting equations describe duct natural frequency as a function of duct areas and volumes, and damping ratio as a function of the slope of the steady-state mass flow, pressure-recovery curve. The calculated response agrees, to a first approximation, with measured response as obtained from wind-tunnel tests of a fixed-geometry, sugar-scoop inlet model with bypass for matching airflows. Further agreement was obtained during flight tests of the F8U-3 airplane.

CONTOUR NOZZLES. E. M. Landsbaum. (ARS 13th Annual Meeting, New York, Nov. 17-21, 1958.) ARS J., Mar., 1960, pp. 244-250. 20 refs. Army-sponsored presentation of the length, weight, and thrust coefficients for a set of contour nozzles for a gas with a specific heat ratio, γ, of 1.22. The design is based upon the assumption of a radial flow section in the initial divergent section which is turned to a uniform axially directed flow at the exit. For each specified exit Mach number, about 95% of the maximum expansion angles were used. The contours obtained were cut back in order to yield nozzles of various exit areas. The surface area of the divergent section, thrust coefficient, and length of these cutback nozzles are compared with those properties of 15° half-angle conical nozzles with the same exit area. Simple heat flux calculations for some of the designs are also presented. These designs result in moderate savings in length, surface area, and heat flux over a 15° nozzle with the same thrust coefficient.

Performance

AN OPTIMIZATION STUDY OF EFFECTS ON AIRCRAFT PERFORMANCE OF VARIOUS

FORMS OF HEAT ADDITION. Appendix A, B - EVALUATION OF ENGINE PARAMETERS FROM EXPERIMENTAL DATA. Appendix C - ARGUMENT FOR INCLUDING FUSELAGE DRAG IN ENGINE DRAG TERM. B. S. Baldwin, Jr. US, NASA TN D-74, Mar., 1960. 48 pp. 25 refs. Review of ram-jet aircraft design considerations at a level of simplification appropriate for evaluation of external heat addition schemes. No definite conclusions are given as to the relative advantage of external combustion in comparison with conventional ram-jet combustion because of the incompleteness of the knowledge of both at hypersonic speeds. Instead, similarity parameters are derived which allow a ready comparison when complete data become available. Possible variations of quantities, such as wing size relative to engine size, which would affect the comparison are eliminated from consideration by deriving the optimum values.

Stability & Control

SUBSONIC WIND-TUNNEL INVESTIGATION OF THE AERODYNAMIC EFFECTS OF PIVOTING A LOW-ASPECT-RATIO WING TO LARGE YAW ANGLES WITH RESPECT TO THE FUSELAGE TO INCREASE LIFT-DRAG RATIO. T. G. Gainer. US, NASA TN D-225, Mar., 1960. 20 pp. Study of a fuselage in combination with low-aspect-ratio wings of various plan forms to determine the effects of pivoting the wing as a unit to extreme angles in the yaw direction with respect to the fuselage to increase its aspect ratio. Three wing plan forms were tested - a delta, a diamond, and a rectangle - with the wing pivoted at angles between the wing and fuselage center lines from 0° to 109°. The results indicated that low values of lift-curve slope and maximum lift-drag ratio inherent in the low-aspect-ratio plan forms could be increased by pivoting the wing. Pivoting the wing generally had little effect on the static longitudinal instability of the delta-wing model with pitching moments referred to the wing pivot point, and a stable pitching-moment variation was obtained by adding a horizontal tail. The longitudinal instability of the diamond- and rectangular-wing models was decreased by pivoting the wing.

THE EFFECTS OF THRUST REVERSAL AT MACH NUMBERS UP TO 0.86 ON THE LONGITUDINAL AND BUFFETING CHARACTERISTICS OF A TYPICAL JET-TRANSPORT AIRPLANE CONFIGURATION. F. B. Sutton and J. J. Brownson. US, NASA TN D-136, Mar., 1960. 93 pp. Discussion of wind-tunnel tests conducted through ranges of angles of attack and jet-pressure ratios for forward and reverse thrust at Mach numbers from 0.40 to 0.86. The results show that thrust reversal can be used as a very effective speed control for jet-transport-type airplanes making high-speed descents from cruising altitudes. The effects of thrust reversal on the longitudinal and buffeting characteristics of the model were not large.

Wings & Airfoils

THE PRESSURE DISTRIBUTION ON A WING WITH A SUBSONIC LEADING EDGE IN THE PRESENCE OF ANTI-SYMMETRIC BODY SHAPING. J. G. Jones. Aero. Quart., Feb., Pt. I, 1960, pp. 51-70. Study of a region on a wing-body combination in which the pressure on the wing is due to the direct effect of body shaping on the same side and to the effect of the upwash field between the leading edge and the upstream limit of the body-shaping effect. Two particular cases are examined in which explicit expressions involving tabulated functions for the pressure distribution due to the upwash field can be obtained. The two cases are: (1) body distortions in which the cross sections are circular and (2) body distortions of arbitrary cross section, but with the restriction that the leading edge is nearly-sonic. As an example, the case where the subsonic leading edge extends right into the body side and anti-symmetric shaping starts at the root leading edge is discussed.

OSCILLATORY AERODYNAMIC COEFFICIENTS FOR A UNIFIED SUPERSONIC-HYPERSONIC STRIP THEORY. W. P. Rodden and J. D. Revell. J. Aero/Space Sci., June, 1960, pp. 451-459. Derivation of oscillatory aerodynamic coefficients for wings with supersonic leading edges from the second-order nonlinear unsteady supersonic flow theory of Van Dyke. The coefficients are modified for sweep, and a finite-span correction is suggested to increase the accuracy of strip-theory flutter analyses. The limiting values of the coefficients in steady flow are also discussed.

SUPERSONIC, SUBSONIC AND SONIC FLOW OVER SLENDER WINGS AT ZERO LIFT. D. G. Randall. Gt. Brit., RAE TN Aero. 2653, Dec., 1959. 30 pp. Presentation of calculation methods for the various velocity regimes. Supersonic and subsonic flows are treated by standard methods, except that a technique is developed for correcting subsonic slender wing theory near a trailing edge (a region in which the theory is invalid). Transonic flow is treated by the equivalence theorem of Oswatitsch and Keune, and a time-saving modification is introduced. The methods are applied to a delta wing with a Lord V area distribution.

PRESSURE DISTRIBUTION AT ZERO LIFT FOR DELTA WINGS WITH RHOMBIC CROSS SECTIONS. E. Eminton. Gt. Brit., RAE TN Aero. 2657, Oct., 1959. 24 pp. Application of the linearized theory of thin wings to the calculation of pressure distributions over delta wings with rhombic cross sections. The program written for DEUCE is described, and the results are compared to those obtained by means of the slender thin wing theory.

A METHOD FOR CALCULATING THE VELOCITY DISTRIBUTION ON A THIN SLENDER WING COMBINED WITH A CYLINDRICAL BODY OF REVOLUTION. G. G. Brebner. Gt. Brit., RAE TN Aero. 2652, Dec., 1959. 19 pp. Analysis considering the calculation of velocity distribution over wing-body combinations where it may not be justifiable to satisfy the boundary conditions on the whole of the median plane because of the rapid variation of thickness in the spanwise direction

near the wing-body junction. An alternative approach to thin wing theory is suggested, by which the exposed thin wing is represented by a distribution of sources in the median plane and the slenderness assumptions are retained so that the problem becomes a two-dimensional one in transverse planes. The potential due to these sources and their images in the body are then calculated on the surface of the body and on the median plane of the exposed wing. A particular example is chosen, a thin ogee wing with parabolic biconvex root profile and cross sections combined with a cylindrical body of revolution. Equations are derived for the potential and its first and second derivatives with respect to x and y.

A STUDY OF CONFIGURATIONS COMPOSED OF A BODY UNDER A LIFTING WING IN SUPERSONIC FLOW. C. F. Chen and J. H. Clarke. Brown U. Div. Eng. Rep. (AFOSR TN 59-1276), Jan., 1960. 62 pp. 18 refs. USAF-Navy-supported analysis of supersonic aircraft configurations composed of a cambered body positioned at a certain distance beneath an arbitrary lifting wing. Expressions for the drag and lift are obtained from reverse-flow considerations, and the drag advantage to be gained when a given body and wing assume a given orientation is studied. Treated more extensively is the variational problem of determining the optimum wing incidence and optimum body shape, for the given volume and length, to yield the minimum drag for prescribed lift. It is found that at a low gap between wing and body, moderate body distortions have a significant influence on the drag. Drag reductions of up to 44% relative to the case of no interference have been found at a Mach number of 2.24 in a configuration having a gap approximately equal to the maximum diameter of the body, and a wing chord of about 3/8 the length of the body.

TESTS OF A CONFIGURATION COMPOSED OF A BODY UNDER A LIFTING WING IN SUPERSONIC FLOW. C. F. Chen. Brown U. Div. Eng. TR WT-31 (AFOSR TN 59-1275), Feb., 1960. 10 pp. Investigation of an arrangement consisting of a Sears-Haack body located under a lifting rectangular diamond profile wing. Tests were made at a Mach number of 1.6 and a Reynolds number of 9.17×10^5, based on body length. It is found that the measured lift developed on the wing, due to the flow field of the body, agrees very well with the theoretical value. Downstream of the impinging shock from the wing, flow separation was observed on the exterior side of the body but not on the interior side. The separation is attributed not to the pressure rise across the shock but to the pressure field arising from the reflection from the body of the shock-induced cross flow. Further observations suggest that the separation can be avoided by pitching the body or by kinking the body at the shock wave to accommodate the shock-induced cross flow.

METHODS OF COMPUTING AVERAGE PROJECTED AREA DISTRIBUTIONS OF WING THICKNESS FOR SUPERSONIC AREA RULING OF WING-BODY COMBINATIONS. B. M. Ryan. Douglas Rep. SM-23791, Dec., 1959. 17 pp. Study of several variations of an approximate method for computing the average projected area distribution of an elliptical wing with optimum thickness distribution, and comparison with an exact analytical method developed by Licher. The "best" method is chosen and applied to delta wings with double wedge and modified double wedge profiles.

AEROELASTICITY

AEROELASTIC INSTABILITIES OF A SLENDER WING-BODY COMBINATION. Teruo Ichikawa. Japan Soc. Aero. & Space Sci. J., Jan., 1960, pp. 1-6. In Japanese, with summary in English. Application of Miles' unsteady aerodynamic theory for a slender body to the study of aeroelastic instability. The results show that both static and dynamic instability can occur. The static instability is caused by loss of restoring moment due to body bending. The dynamic instability appears in the form of a coupled pitch-bending oscillation which can be prevented by locating the wing aft of the first bending nodal point.

VIBRATION OF RECTANGULAR PLATES POINT-SUPPORTED AT THE CORNERS. H. L. Cox and Jack Boxer. Aero. Quart., Feb., Pt. I, 1960, pp. 41-50. Calculation of the fundamental frequencies of flexural vibration for uniform isotropic rectangular plates that have free edges and pinpoint supports at the four corners. For the particular case of a square plate the lowest five frequencies and mode shapes are determined. The second frequency is most unusual, since an infinite number of mode shapes exist with identical frequencies. Finite difference expressions, which simplify the treatment of the free boundaries for definite values of Poisson's ratio, are used in conjunction with extrapolation procedures to obtain the approximate solutions.

FUELS & LUBRICANTS

COMBUSTION OF HIGHLY REACTIVE FUELS IN SUPERSONIC AIRSTREAMS. E. A. Fletcher, R. G. Dorsch, and Harrison Allen, Jr. ARS J., Apr., 1960, pp. 337-344. 12 refs. Study of the feasibility of achieving combustion in supersonic airstreams with several fuels and description of some combustion and flow phenomena which were observed in a small wind tunnel with aluminum borohydride. Aluminum borohydride, pentaborane, hydrocarbon-aluminum borohydride mixtures, trimethylaluminum, diethylaluminum hydride, alkylboranes, alkylboron hydrides, and vinylsilane were tested. The first three ignited easily and burned well. The others either failed to ignite or burned only in the diffuser. Trimethylaluminum and diethylaluminum hydride produced light and other evidence of heat evolution when water was simultaneously injected into the tunnel. Gross effects on flow were studied by observation of shock patterns and water sprays injected from the tunnel walls. Examples are given which illustrate the use of these techniques in aerodynamic studies in larger wind tunnels.

MATERIALS

Metals & Alloys

ON STRESS INTERACTION IN FATIGUE AND A CUMULATIVE DAMAGE RULE. II - 7075 ALUMINUM ALLOY. A. M. Freudenthal and R. A. Heller. USAF WADC TR 58-69, Pt. II, Jan., 1960. 17 pp. Investigation to determine the effects of stress interaction, under randomized stress distributions representing gust and maneuver loads on aircraft wings, on the fatigue life of 7075 aluminum alloy specimens. On the basis of numerous rotating bending fatigue tests, it is demonstrated that the linear cumulative damage rule does not provide a safe fatigue life estimate of unnotched specimens. A nonlinear rule representing the test results fairly well is proposed.

MATHEMATICS

Physical Applications

A COMPILATION OF COÖRDINATE TRANSFORMATIONS APPLIED TO THE BOUNDARY-LAYER EQUATIONS FOR LAMINAR FLOWS. E. Y. Ch. Sun. DVL Bericht No. 121, Mar., 1960. 42 pp. 22 refs. Westdeutscher Verlag, Köln & Opladen. Presentation of five basic transformations and 14 variations for the differential equations of laminar boundary-layer problems. The five basic transformations include the generalized similarity transformation, von Mises' transformation, Crocco's transformation, Mangler's transformation, and Howarth's transformation. For some of these basic transformations and their variations, an attempt has been made to derive the transformation variables, so that the inherent purpose of the transformation in question might be rendered more apparent.

MISSILE, ROCKET, & SPACE TECHNOLOGY

STRUCTURAL DAMAGE AND OTHER EFFECTS OF SOLAR PLASMAS. L. Reiffel. ARS J., Mar., 1960, pp. 258-262. 29 refs. Study of the detrimental effect of solar plasmas on the performance of various thin lightweight structures which might be erected in space outside of magnetically protected regions. The damaging effects of solar plasma streams are shown to be potentially serious and may result in low durability or high payload penalties. Estimates given depend directly on plasma stream densities and velocities which are only approximately known. However, a reduction by one order of magnitude or more in widely held current estimates of the properties of the solar plasma would still imply a considerable effect on particular structural materials. Substances used as thin coatings on more massive structures would be similarly affected.

RELATIVISTIC THEORY OF ROCKET FLIGHT WITH ADVANCED PROPULSION SYSTEMS. John Huth. ARS J., Mar., 1960, pp. 250-253. Presentation of a general relativistic theory of rocket propulsion, applicable to either adiabatic or diabatic jets, and to several methods for handling fuel residual. Emphasis is given to the performance limitations imposed by both fuel energetics and power supply weight. An example shows the shift in importance from fuel energetics to power plant weight as the allowable mission time shrinks. Long flight times and high efficiency, lightweight energy conversion equipment both tend toward increasing the relative role played by fuel mass. A photon rocket cannot be the optimum choice unless there is a complete mass annihilation energy source and massless conversion equipment.

COMPARISON OF CHEMICAL AND ELECTRIC PROPULSION SYSTEMS FOR INTERPLANETARY TRAVEL. Appendix - ORBITS IN AN INVERSE-SQUARE CENTRAL FIELD. C. Saltzer, R. T. Craig, and C. W. Fetheroff. IRE Proc., Apr., 1960, pp. 465-476. USAF-sponsored discussion of the basic mission parameters which are required for the evaluation of engine performance for interplanetary flights. The engine parameters are defined, and the relation between these parameters is formulated. The possibility of achieving much larger payload fractions by the use of electric propulsion systems, as opposed to the use of chemical propulsion systems, is indicated. Methods of calculating impulsive orbit transfers between circular orbits, escape and entry from satellite orbits using low thrust, and optimized powered transfer between heliocentric orbits are given.

ELECTRICALLY-CONTROLLED DEMAND-THRUST ROCKETS FOR SATELLITE GUIDANCE. D. D. Ordahl. IRE Proc., Apr., 1960, pp. 517-519. Study of the military and scientific uses and the technical requirements for satellites which can be positioned precisely in space. Typical applications include meteorological observations, communications, atmospheric research, and, ultimately, soft-landing vehicles for manned space travel. To accomplish accurate control of orbit and/or attitude with rocket motors, extremely precise regulation of thrusts is required, generally in the range between 0 to 1 or 0 to 10 lbs. It must be possible to turn these control forces on and off in a few millisec. repeatedly or intermittently over periods of several months to perhaps several years. For use in such applications, rocket units are investigated which employ the combination of storable-liquid propellants and demand-thrust injectors capable of complete remote control.

PUNCTURE PROBLEM AT COSMIC VELOCITIES. M. A. Lavrent'ev. (Iskusstv. Sputniki Zemli, No. 3, 1959, pp. 61-65.) ARS J. Suppl., Apr., 1960, pp. 386-388. Translation. Study of the puncture problem for metallic plates at velocities of 50 to 100 km. per sec. A model of an incompressible medium is proposed, from which it is possible to conduct calculations up to the desired limit. A one-dimensional case is considered. The problem of the impact of a plate of thickness a, flying at a velocity v_0, on the end of a cylinder of length ℓ is studied. The problem consists in determining the impulse which the rod acquires as a result of the impact. Under an inelastic impact, the block of the first plate retains

a quantity of motion, and as a result of the increase of mass, a loss of kinetic energy accurs. The three-dimensional case involves the impact of a pellet against a plate-hemisphere of given radius. As a result of the impact, the mass of the pellet will increase in accordance with the concept of inelastic collisions; with the increase of mass, the amount of motion will be preserved, but the kinetic energy of the system will be converted into heat.

RESEARCH DIRECTED TOWARD THE DESIGN, DEVELOPMENT, AND CONSTRUCTION OF METEORITIC MICROPHONE DETECTORS OF VARIOUS SENSITIVITIES FOR USE IN SATELLITES. H. E. Harrington. Okla. State U. Res. Found. Sci. Rep. 1 (AFCRC TN 60-229), Jan. 15, 1960. 30 pp. Development of an electronic system designed to obtain information regarding the influx of micrometeor material. An acoustic sensing technique is employed, whereby the particular matter to be detected activates a supersonic microphone device. The resultant electrical signal is amplified to a suitable level, graded as to magnitude, and stored internally by electronic means for subsequent recording and/or telemetering to ground receiving stations by the system inherently available within the chosen vehicle. The prototype equipment has been subjected to a testing program to verify its suitability for the anticipated use, and several sets are currently under construction.

METHODS OF COMBATTING INTERFERING CURRENTS THAT ARISE AT THE INPUT OF AN ELECTROSTATIC FLUXMETER OPERATING IN A CONDUCTING MEDIUM. I. M. Imyanitov and Ya. M. Shvartz. (Iskusstv. Sputniki Zemli, No. 3, 1959, pp. 77-83.) ARS J. Suppl., Apr., 1960, pp. 403-406. Translation. Presentation of a brief description of a rotary-type electrostatic fluxmeter used for measuring the natural charge of a satellite. Noise currents appearing at the input of the measuring circuit and raising the lower limit of the recorded natural charge of the satellite appear to be the result of the following: (1) velocity of the satellite relative to the thermal velocities of ions and electrons, (2) the difference between the potential of the satellite at the position of the fluxmeter and the equilibrium value of potential, (3) exposure to various types of photoemission, and (4) directed movements. One method for decreasing interfering currents uses a synchronous detector at the output of the measuring circuit of the fluxmeter. Another method involves designing the measuring and screening plates of the fluxmeter so as to decrease both the modulation of the flow of charged particles reaching the surface and the absolute value of current falling on the surface of the measuring plate. The use of negative feedback on the noise voltage is suggested as another method for controlling interfering currents.

A GENERAL LEAST SQUARES ADJUSTMENT FOR COMPUTING BALLISTIC MISSILE ATTITUDE. G. H. Rosenfield. RCA Data Proc. TR 53 (AFMTC TR 59-22), Sept., 1959. 77 pp. 14 refs. Presentation of a least squares adjustment for computing the three elements of ballistic missile attitude: pitch, yaw, and roll, utilizing images recorded by one or more photogrammetric cameras. The solution directly computes absolute attitude using missile image exposed on a single photographic frame. Camera orientation, coordinates of selected points on the missile, and film measurements are required in the reduction. A minimum of three points are required for a solution from one camera. An outline of the computational program and a numerical example are presented to facilitate programing for electronic computation.

THE OPTIMIZATION OF ASTRONAUTICAL VEHICLE DETECTION SYSTEMS THROUGH THE APPLICATION OF SEARCH THEORY. N. S. Potter. IRE Proc., Apr., 1960, pp. 541-553. Presentation of a generalized theory of detection system performance and its application to the analysis of collision warning and the optimal allocation of search effort for astronautical vehicles. The kinematic basis of the relative frequency of intercepts with randomly moving particles is presented. The pronounced variation in warning system effectiveness, if the possible contact space is uniformly scanned, is displayed by investigating the functional behavior of the weighted mean acquisition range and cumulative probability of detection by some minimal detection barrier in the hypervelocity closure rate, low signal amplitude operational environment. The rational choice of the frame time is investigated in terms of the information rate out of the sensor and the requirements of the decision-making apparatus. The important case of contacts between astronauts and other objects independently moving on trajectories defined by a generalized central force field is also considered.

THE LONG-TIME SATELLITE RENDEZVOUS TRAJECTORY. L. W. Spradlin. Aero/Space Engrg., June, 1960, pp. 32-37. Description of a method of achieving rendezvous with a satellite which is in circular orbit. Steering equations are given which express the desired velocity as a function of position and time. The transfer maneuver is performed by the application of two thrust impulses, which produce step changes in the commuter's velocity initially and at the completion of the maneuver. The resulting S-frame trajectory of the commuter can be calculated by considering the initial conditions of velocity to be measured at $t = 0^+$, after the first impulse. The resulting trajectory is essentially a coasting one, except for the initial and final impulses. However, this is not a true minimum-fuel rendezvous maneuver unless the initial conditions and the specified total time are those which correspond to a Hohmann transfer.

Ballistics, Re-Entry

ASCENT FROM INNER CIRCULAR TO OUTER CO-PLANAR ELLIPTIC ORBITS. L. Rider. ARS J., Mar., 1960, pp. 254-258. Derivation of

the general energy requirement in terms of a characteristic velocity for the ascent from an initial circular parking orbit to any outer coplanar elliptical orbit by a two-instantaneous-impulse, cotangential transfer. The analysis is performed as a function of the location of the second impulse on the final orbit. It is shown that injection at final orbit apogee is the most economical, whereas injection at final orbit perigee is the least economical. For the special case of final orbit perigee located on the initial parking orbit, the most economical transfer requires a single impulse applied at perigee.

MINIMUM TIME FLIGHT PATHS. G. M. Schindler. ARS J., Apr., 1960, pp. 352-355. Derivation of a general condition which must be satisfied by an aircraft or space vehicle in order to reach a predetermined point in a minimum time. The thrust, lift, and drag can depend in an arbitrary manner on the instantaneous position and velocity coordinates (or Mach number), as well as on the angle of attack between the directions of the thrust and the velocity. In order to make the solution applicable to space vehicles as well as to aircraft, the cases of a spherical and a flat earth are treated separately.

THE VARIATION AND CONTROL OF RANGE TRAVELED IN THE ATMOSPHERE BY A HIGH-DRAG VARIABLE-LIFT ENTRY VEHICLE. Appendix - EQUATIONS OF MOTION FOR ROTATING EARTH AND ATMOSPHERE. D. C. Cheatham, J. W. Young, and J. M. Eggleston. US, NASA TN D-230, Mar., 1960. 41 pp. Study of the effect on range of such factors as entry angle, angle of attack, wing loading, initial velocity, orbital heading, and initial latitude. Results are also presented which show the feasibility of an automatic control that regulates angle of attack in such a manner as to control the trajectory of the vehicle to a desired landing area. Results using the method of range control show that the range could be controlled to within $\pm$ 20 miles of the desired location by the time an altitude of 100,000 ft. is reached.

EFFECTS OF SMALL CHANGES IN POSITION AND VELOCITY AT BURNOUT ON THE ORBIT OF A BALLISTIC MISSILE. E. E. Perret and J. C. Corbin, Jr. USAF WADC TN 59-336, Oct., 1959. 25 pp. Analysis showing that assumed spherical distributions of error in position or velocity at burnout propagate as error ellipsoids of position for increasing eccentricity with time. The results can be used to assess the accuracy required in establishing the position and velocity of the missile at burnout (1) to accomplish interception at various points on the orbit (defensive sense), or (2) to achieve a desired circular probable error at impact (offensive sense). In addition, the relative motion of closely spaced missiles and/or decoys having the same or slightly different velocities can be examined.

OPTIMUM RE-ENTRY INTO THE EARTH'S ATMOSPHERE BY USE OF A VARIABLE CONTROL FORCE. F. J. Marshall. USAF WADC TR 59-515, Oct., 1959. 127 pp. 83 refs. Study of the mechanics of re-entry and formulation of a list of design requirements, which are translated as mathematical constraints. A series of problems based on the pertinent constraint from this listing are then formulated, solved, and the solutions interpreted in terms of the hardware of the proposed vehicle. The problems stem from the four fundamental systems intrinsic to the re-entry problem. These systems are the following: (1) an aerodynamically-controlled body with radiant cooling, (2) a thrust-controlled body with radiant cooling, (3) an aerodynamically-controlled body with nonradiant cooling, and (4) a thrust-controlled body with nonradiant cooling. The particular problems have a variety of constraints dependent upon the particular system under consideration and a variety of end conditions, -- e.g., the soft landing ($v_f = 0$) and the hard landing (v_f arbitrary).

EFFECTS OF NOSE CORNER RADII, AFTERBODY SECTION DEFLECTIONS, AND A DROGUE CHUTE ON SUBSONIC MOTIONS OF MANNED-SATELLITE MODELS IN REENTRY CONFIGURATION. W. S. Blanchard, Jr., and Sherwood Hoffman. US, NASA TN D-223, Mar., 1960. 16 pp. Investigation on the basic shape with various nose corner radii showing amplitudes of steady state oscillations that varied from about $\pm 45^\circ$ with the sharp cornered nose to approximately $\pm 60^\circ$ with the larger nose radii. The addition of a drogue chute or afterbody section deflections caused large reductions in the amplitude of the oscillations. The model with large corner radii and open afterbody had virtually no residual oscillations.

Guidance, Control, Stability

STABILITY OF ROTATING SPACE VEHICLES. H. L. Newkirk, W. R. Haseltine, and A. V. Pratt. IRE Proc., Apr., 1960, pp. 743-750. 12 refs. Study showing that, at least for some applications, the intrinsic stabilization obtained by rotation of the entire vehicle is advantageous. Investigations which have been made of natural methods for damping nutational vibrations of such rotating vehicles are discussed. A laboratory simulator is described which has been found very useful in testing the various devices suggested for nutation damping. A number of references to recent analytical studies of nutation dampers are given. One approach, a rigorous attack on a simplified arrangement, is described. Also, formulas based on an intuitive approach are derived for the design of both the pendulum and the mercury dampers. Finally, a new basic design criterion for stable operation of coupled rotating bodies, such as a space vehicle with pendulum nutation dampers, is demonstrated.

PRINCIPLES OF ATTITUDE CONTROL OF ARTIFICIAL SATELLITES. Appendix - GRAVITATIONAL TORQUE ON THE SATELLITE CONFIGURATION. N. E. Ives. Gt. Brit., RAE TN G.W. 534, Nov., 1959. 35 pp. Derivation of equations of attitude motion for small angular dis-

placements from the equilibrium position of an earth-pointing satellite employing reaction flywheel damping. This is followed by a discussion on the attitude control against the gravitational torque due to the earth and the use of reaction-jets for the control of a spherical satellite configuration; finally, a single plane analytical account is given of a method of eliminating any undesirable momentum which the satellite may possess immediately after it leaves the carrier missile for its future orbit.

Spacecraft

THE MOTION OF A ROTATING SATELLITE OF CYLINDRICAL SHAPE IN THE ATMOSPHERE. Peter Notni and Hans Oleak. (Veröffentl. Sternwarte, Babelsberg, No. 3, 1959.) Gt. Brit., RAE Lib. Transl. 868, Jan., 1960. 23 pp. Derivation of formulas for a very long rotating satellite of cylindrical shape, which enable the acceleration of the orbit and the lengthening of the rotation period to be computed. In addition, formulas are given for the precession of the axis of rotation.

ESTABLISHMENT OF A CIRCULAR SATELLITE ORBIT BY DOUBLE IMPULSE. G. Leitmann. Brit. Interpl. Soc. J., Jan.-Feb., 1960, pp. 194-198. Analysis considering the optimum direction of launch and the staging of a two-stage satellite carrier required to establish a given payload in a circular orbit of prescribed radius using a minimum amount of fuel. It is shown that, for the ideal model of vacuum flight over a rotating, spherical earth and an impulsive thrust application, the ratio of stage specific impulses is the governing parameter. Horizontal launch toward the east is best above a certain value of the specific impulse ratio. When this ratio drops below a critical value, a vertical velocity component is required at launch. It is also shown that fuel consumption has a maximum for a finite radius orbit.

THE COMBINED NON-LINEAR EFFECTS OF EARTH OBLATENESS AND ATMOSPHERIC DRAG ON A NEAR-EARTH SATELLITE. Appendix I - THE ORBIT OF A NEAR-EARTH SATELLITE. Appendix II - ERROR ANALYSIS ON THE INITIAL ORBITAL ELEMENTS AND COORDINATES OF THE ORBIT OF A NEAR-EARTH SATELLITE DUE TO ERRORS IN THE INITIAL CONDITIONS. T. J. Jaramillo. USAF WADC TR 59-513, Oct., 1959. 103 pp. 38 refs. Presentation of sets of equations which may be used in calculating the positions of an earth satellite moving under the influence of an attracting oblate earth and air drag, assuming the air density to decrease exponentially with height. The six elements of the initial elliptical orbit are expressed in terms of the initial conditions at burnout point, and equations are derived for obtaining the errors induced in the elements by the errors inherent in the initial conditions. Because of oblateness and air drag, these six orbital elements are not constants, but vary with time. The air drag does not affect the longitude of the nodes and the inclination of the plane of the orbit, but it causes an oscillation in the argument of the perigee point (ω) with a finite amplitude, which vanishes at the end of a complete revolution of the satellite. The major semi-axis (a), the eccentricity (e), and the period (P) are decreased at ever increasing rates by air drag.

NAVIGATION

A SATELLITE DOPPLER NAVIGATION SYSTEM. Appendix - EQUATIONS FOR THE DOPPLER SHIFT IN THE PRESENCE OF THE EARTH'S IONOSPHERE. W. H. Guier and G. C. Weiffenbach. IRE Proc., Apr., 1960, pp. 507-516. Navy-supported presentation of a satellite Doppler navigation system which conveniently provides navigators with all necessary inputs for position calculation, including up-to-date orbital data. Also presented are the results of a comprehensive error analysis which proves the feasibility of achieving navigational accuracies of one-half mile using such a system under realistic conditions.

INERTIAL-GUIDANCE LIMITATIONS IMPOSED BY FLUCTUATION PHENOMENA IN GYROSCOPES. G. C. Newton, Jr. IRE Proc., Apr., 1960, pp. 520-527. Investigation of the performance limitations imposed by thermal fluctuations in gyroscopes, pointing out that experience in electronics shows that thermal noise is the ultimate performance limitation in sensitive instruments such as radio receivers and galvanometers. It is found that a system limited only by thermal noise in its gyroscopes would have several orders of magnitude more precision than that indicated in published performance data. This must mean that other factors are limiting the performance of gyroscopes, and an investigation of several of these shows that bearing noise may be an important one.

PHYSICS

Geophysics

SOME RESULTS OF THE DETERMINATION OF THE STRUCTURAL PARAMETERS OF THE ATMOSPHERE USING THE THIRD SOVIET ARTIFICIAL EARTH SATELLITE. V. V. Mikhnevich, B. S. Denilin, A. I. Repnev, and V. A. Sokolov. (Iskusstv. Sputniki Zemli, No. 3, 1959, pp. 84-97.) ARS J. Suppl., Apr., 1960, pp. 407-413. 37 refs. Translation. Presentation of results from the processing of manometric measurements conducted on the 16th pass of the third Soviet satellite, which represents the state of the atmosphere at altitudes from 228 to 500 km. on May 16, 1958. Values for different altitudes correspond to measurements obtained at different times of the day and at different latitudes. Design and operation of satellite-borne manometric equipment and the method for determining atmospheric values are described. Calculations of the altitude of homogeneous atmosphere, temperature, and pressure were performed on the assumption of the applicability of normal barometric formulas to a rarefied gas in the presence of temperature gradients. Data are presented on the values of density at different altitudes as obtained in USSR and USA through manometric measurements and satellite

drag. The survey of information confirms the fact that the state of the upper surface of the atmosphere can change sharply, depending on such factors as outer disturbances, as well as the season, time of day, and geographical latitude.

POWER PLANTS

ELECTROSTATIC PROPULSION. IRE Proc., Apr., 1960, pp. 477-491. 20 refs. USAF-sponsored analysis and discussion of electrostatic thrust engines and their theory. The thrust (newtons) developed by a system which accelerates a space charge limited flow of ions of specific charge q/m (coulombs per kg.) through a voltage V is given by $F=(2\pi/q)_{\epsilon_0} V^2R^2=\sqrt{2m/qV^2P}$. R is an aspect ratio of ion beam diameter to acceleration distance x_0, and P is a diode perveance (amp./volts$^{3/2}$). Lines of electric force extend from charges in transit across the diode to charged surfaces of the accelerator electrode, on which the thrust is thus purely electrostatic. The use of alkali metals as propellants and their characteristics are discussed. Mathematical solutions to the neutralization problem for the case of one-dimensional flow of mixed ion and electron beams are presented, assuming no energy exchanges by collisions or plasma instabilities. It is concluded that numerous closely-spaced electron injectors must be used, and that the total electron circulating current must have orders of magnitude greater than the ion current. Finally, if particles having much smaller specific charge than elemental ions could be copiously produced and accelerated, practically useful thrusts could be gained from pencil beam at $R \approx 1$. The complications of neutralization would then probably be eliminated.

A COMPARISON OF ION AND PLASMA PROPULSION. S. W. Kash. IRE Proc., Apr., 1960, pp. 458-465. 10 refs. Comparative study of important features and parameters of ion and plasma accelerators. Estimates for the thrust of individual ion and plasma acceleration units, and impulse measurements for a collinear electrode plasma accelerator, are given. It is found that the maximum thrust for an ion gun does not depend on the diameter of the beam, but primarily on the accelerating voltage. Because of the relatively small thrust of the ion accelerator, a greater number of them will be required for a given total amount of thrust. Beam neutralization is found to be a problem peculiar to the ion accelerator. An estimate of the power for neutralization is made. The variation of efficiency with specific impulse is discussed. Erosion is a serious problem in electrical propulsion; however, for a plasma accelerator it may actually be utilized to provide the propellant material.

ANALYSIS OF ONE-DIMENSIONAL ION ROCKET WITH GRID NEUTRALIZATION. Appendix A, B - ONE-DIMENSIONAL CHARGED BEAM WITHOUT CURRENT REVERSAL. Appendix C - ONE-DIMENSIONAL CHARGED BEAM WITH CURRENT REVERSAL. Appendix D - MOMENTUM-INTEGRAL METHOD FOR THRUST EVALUATION. Harold Mirels and B. M. Rosenbaum. US, NASA TN D-266, Mar., 1960. 43 pp. 15 refs. Study of a rocket consisting of a grid that emits ions, a grid that accelerates the ions, and a grid that neutralizes them (by the emission of electrons). The ion beam between the ion-emitting grid and the neutralization grid is determined, as is the mixed ion-electron beam downstream (and sometimes upstream) of the neutralization grid. The mixed ion-electron beam is found to have a small-wavelength, small-amplitude periodic wave structure. The forces on the individual grids and the overall thrust of the ion rocket are also determined using momentum-integral concepts.

PHOTON PROPELLED SPACE VEHICLES. D. C. Hock, F. N. McMillan, and A. R. Tanguay. IRE Proc., Apr., 1960, pp. 492-496. Analysis of interplanetary trajectories of vehicles propelled by solar radiation pressure. The trajectories are shown to be logarithmic spirals if thrust direction is constant with respect to the vehicle-sun line. The required thrust may be obtained with a solar sail. Sail size as a function of trip time to Mars is determined for solar thrust, oriented tangent to the trajectory. Solar propulsion is compared with chemical and electrical propulsion. It is shown that a solar-sail-powered space vehicle on a journey from Earth to Mars operates with a payload and flight time penalty when compared with a ballistic vehicle. However, the work capacity per unit weight of a solar sail is calculated to be superior to an electrical engine which, in turn, is vastly superior to a chemical engine when the work is compared on the basis of equal flight times.

Jet & Turbine

MECANISME DE LA DEVIATION DES JETS PROPULSIFS. M. Kadosch. France, Min. de l'Air BST 124, Nov., 1959. 156 pp. 19 refs. SDIT, 2 Av. Porte-d'Issy, Paris 15, Frs. 4,300. In French. Historical survey covering theoretical and experimental investigations of various problems of jet deflection; application of thrust reversal in landing operations; description of various jet deflectors and their basic principles of operation; theoretical studies of deflection by obstacles or by blowing, including the effect of various variables such as incompressibility or compressibility of the fluid, wall effect, and slot size; application of calculated data to the scaling of thrust reversers, with emphasis on certain specific cases; experimental study covering the deviation and striction, symmetric deviation, Mach number effect, results for supersonic flow, and shock waves; and theory of the Young effect concerning transversal and longitudinal pressure gradients, as well as comparison with the combined obstacle-wall technique.

SOME PRACTICAL ASPECTS OF COMPRESSOR BLADE VIBRATION. E. K. Armstrong and R. E. Stevenson. RAeS J., Mar., 1960, pp. 117-130. Study of the types of vibration to be found in a compressor, their identification, and their treatment in engine blade problems. The four classes

are the fixed wake excitation, flutter, rotating stall cell excitation, and random types of vibration. It is concluded that, except for wake excitation, the design factors for controlling blade vibration are largely semiempirical. In the case of wake excitation, it is found that serious amplitudes are not likely to arise with conventional designs, if the basic resonances of the lowest four modes of vibration with main obstructions such as intake vanes are removed from the engine speed range between idling and take-off. To accommodate the general level of vibration and the lower random vibrations, the compressor blades should be stressed to withstand a minimum vibration of 2 ft. per sec. For a flutter type of vibration the frequency parameter rule may be used, but it is emphasized that this is strictly an empirical rule which does not explain all the aspects involved in flutter vibrations. It is also concluded that it is not yet possible to predict whether a compressor is likely to be subject to rotating stall cells.

Rocket

PERFORMANCE PROBLEMS IN LARGE ROCKET ENGINES. S. L. Bragg. RAeS J., Mar., 1960, pp. 131-140. Study of design and performance problems for ballistic missile engines. These include the optimum fuel-oxidant operating mixture, thrust chamber heat transfer, combustion inefficiency, injector design, combustion instability such as chugging and screeching, smooth starting, the thrust control program, control of the propellant mixture ratio, cut-off, test instrumentation for measuring mass flow rates, and reliability. It is concluded that the major difficulties that occur are introduced by thrust chamber heat transfer, combustion instability, propellant utilization, cut-off repeatability, and instrumentation.

ROTATING WING AIRCRAFT, HELICOPTERS

CORRELATION STUDY FOR GROUND RESONANCE OF THE HELICOPTER BY THE MODEL TESTS. Motoi Yoshiwaka and Atsuhiko Mori. Japan Soc. Aero. & Space Sci. J., Mar., 1960, pp. 1-7. In Japanese, with summary in English. Review of the theory of Coleman and presentation of the results of experimental investigations on several model rotors and small viscous dampers. The models were built to represent the dynamic system of the rotor head without the freedom in the y-direction to avoid experimental errors. The test results show, as expected, that the viscous dampers and the drag hinge offsets have a large effect on the ground resonance characteristics of the helicopter.

NATURAL FREQUENCIES IN BENDING OF TWISTED ROTATING AND NONROTATING BLADES. G. Isakson and J. G. Eisley. US, NASA TN D-371, Mar., 1960. 67 pp. 12 refs. Analysis of the effect of twist on the natural frequencies of uniform and tapered nonrotating blades and the effect of twist and blade angle on the natural frequencies of rotating uniform blades. The Rayleigh-Southwell procedure for determining the effect of rotation on natural frequencies of beam vibration is evaluated with respect to twisted rotating blades and found to provide a useful approximation only in certain cases. A relation developed by Lo and Renbarger for the effect of blade angle on the natural frequencies of a rotating blade is found to provide a useful approximation, under some circumstances, in the case of the fundamental frequency of a twisted cantilever blade.

STRUCTURES

Bars & Rods

STRUTS WITH LINEARLY VARYING AXIAL LOADING. J. S. Przemieniecki. Aero. Quart., Feb., Pt. I, 1960, pp. 71-98. Derivation of analytical solutions for the deflections and bending moments for struts with axial loading applied either (a) along the underformed straight strut axis or (b) at the strut axis in the deflected position. The instability of struts with various end conditions is discussed and the stability criteria are given as a series of curves relating the maximum compressive axial load with the maximum distributed loading. Explicit formulas for the deflections and bending moment distributions are compiled for several cases of lateral loading combined with the axial loading of the type (a).

Beams & Columns

BUCKLING OF A COLUMN WITH RANDOM INITIAL DISPLACEMENTS. W. E. Boyce. Rensselaer Polytech. Inst. Dept. Math. RPI MathRep. 32 (AFOSR TN 60-150), Feb. 22, 1960. 16 pp. Analysis of the relation between the load and the mean transverse displacement of the column when the initial configuration of the column is random in nature. The solution is presented in terms of a Green's function integral. The problem of ranges of loading for which the scatter in the additional displacement becomes respectively less or greater than the initial displacement, is considered. For small loads, the resulting displacements will also be small and so will their dispersion; for loads near the Euler load, the opposite will be the case.

Fatigue

STRESS DISTRIBUTION AROUND A CENTRAL CRACK IN A PLATE LOADED IN TENSION; EFFECT OF FINITE WIDTH OF PLATE. J. R. Dixon. RAeS J., Mar., 1960, pp. 141-145. Investigation of the effect of the finite width of plate on the elastic-stress distribution due to a central crack. Two-dimensional photoelastic tests were carried out on flat-plate specimens. The photoelastic specimens were similar to the 10-in.-wide fatigue specimens used by Frost and Dugdale, with the central crack simulated by a slot bounded by holes of small radii. A theoretical solution of the problem was derived and compared with the present and other photoelastic results.

Plates

COMBINED EFFECTS OF AXIAL LOAD, THERMAL STRESS, AND CREEP IN FLAT PLATES.

Appendix A - EXPERIMENTAL PROGRAM. Appendix B - THE DETERMINATION OF STRESS DISTRIBUTION IN THE ELASTIC AND PLASTIC RANGE FOR A LONG FLAT PLATE SUBJECTED TO LOAD- AND TEMPERATURE-INDUCED STRESSES FOR SHORT-TIME OR CREEP CONDITIONS. Appendix C - BUCKLING CRITERIA OF SIMPLY SUPPORTED PLATES UNDER THERMAL EFFECTS. Appendix D - DETERMINATION OF EXPERIMENTAL CRITICAL COMPRESSION LOADS. Appendix E - TEST DATA. P. C. Huang and C. J. Van Der Maas. USAF WADC TR 57-442, Mar., 1958. 131 pp. Presentation of two methods for analyzing unevenly heated flat plates. The methods are limited to the analysis of loadings in the plane of the plate and to temperature and strain distributions which are considered one-dimensional. One method calculates the stress distribution under various combinations of heating and tension loading, and the other determines the critical compression stress. The results of experiments using 2024-T4 aluminum are presented, and comparisons are made to verify the theory.

Wings

TESTS OF AERODYNAMICALLY HEATED MULTIWEB WING STRUCTURES IN A FREE JET AT MACH NUMBER 2 - THREE MODELS OF 20-INCH CHORD AND SPAN CONSTRUCTED FROM MAGNESIUM, TITANIUM, AND ALUMINUM ALLOYS, RESPECTIVELY. J. R. Davidson and Richard Rosecrans. US, NASA Memo. 10-12-58L, Oct., 1958. 22 pp. Discussion of experiments with three multiweb wing structures constructed from magnesium, titanium, and aluminum alloy, respectively, which were tested at a Mach number of 2 in a free jet at sea-level static pressure and stagnation temperatures near 520°F. All models experienced a flutter failure after the jet became supersonic but before jet free-stream dynamic pressure reached the full-test-condition value of 42 psi. Natural modes and frequencies obtained from room-temperature vibration tests are presented.

THERMODYNAMICS

METHOD OF CALCULATION OF THE TRANSPORT COEFFICIENTS OF AIR AT HIGH TEMPERATURES. E. V. Stupochenko, B. V. Dotsenko, I. P. Stakhanov, and E. V. Samuilov. ARS J. Suppl., Apr., 1960, pp. 394-402. 11 refs. Translation. Calculation of the coefficients of viscosity and thermal conductivity of air in the temperature range from 2,000° to 8,000°K. and the pressure range from 0.001 to 1,000 atm. The treatment is based on a model in which air is idealized as a binary mixture of "atoms" and "molecules." The problem of predicting the three intermolecular potentials is discussed at some length. In the actual calculations the molecule-molecule interaction is taken to be of a modified Buckingham form and, because of the lack of information, the atom-atom in atom-molecule interactions are taken to be of the simple rigid sphere form. The choice of the rigid sphere diameters is made by an interpolation in the periodic table based on a few known values. The transport of energy in a reacting gas mixture is discussed from the point of view of the thermodynamics of irreversible processes. It is concluded that, if the reaction rates are sufficiently rapid, the transport of energy is described by a simple effective coefficient of conductivity. The results of the calculations are given graphically.

CORRELATION FORMULAS AND TABLES OF DENSITY AND SOME TRANSPORT PROPERTIES OF EQUILIBRIUM DISSOCIATING AIR FOR USE IN SOLUTIONS OF THE BOUNDARY-LAYER EQUATIONS. N. B. Cohen. US, NASA TN D-194, Feb., 1960. 37 pp. 15 refs. Presentation of correlation formulas, tables of density, the product of density and viscosity, Prandtl number, Lewis number, and a diffusion function as functions of enthalpy and pressure. The correlations cover a range in pressure from 10^{-4} atm to 10 atm and an enthalpy range from 128.7 B.t.u. per lb. (corresponding to a temperature of 540°F.) to 16,930 B.t.u. per lb. (corresponding to flight at approximately 29,000 ft. per sec.).

Combustion

RESEARCH ON COMBUSTION PHENOMENA AT HIGH PRESSURES. Rudolph Edse, W. A. Strauss, and M. C. Fong. USAF WADC TN 59-328, Jan., 1959. 23 pp. 11 refs. Investigations conducted on the following combustion systems: (1) the pressure effect on the burning velocity of ammonia-air, ammonia-oxygen and hydrogen-bromine mixtures, (2) the effect of ethyl nitrate on the burning velocity of carbon monoxide - air and methane-oxygen mixtures, and (3) the effect of replacing the nitrogen in rich ethylene-oxygen-nitrogen and rich acetylene-oxygen-nitrogen flames with carbon monoxide. The apparatus, instrumentation, and test methods are described, and the results are discussed.

SPECTROSCOPIC STUDIES OF REVERSE JET FLAME STABILIZATION. A. E. Fuhs. ARS J., Mar., 1960, pp. 238-243. 11 refs. Army-supported study of the conditions in the critical zone which have a strong influence on the stability of a flame held stationary by a small jet directed counter to the main stream. Using the spectral intensity ratio method, the local equivalence ratio in the critical zone is measured. The results suggest that there is one stability curve (blowoff velocity as a function of the equivalence ratio in the critical zone) regardless of jet composition. The equivalence ratio in a reverse jet stabilized flame was determined locally as a function of duct radius. Jet composition affects the observed equivalence ratio radically as far as the duct walls, although only weakly beyond about 1/3 of the duct radius.

CALCULATION OF DETONATION PARAMETERS FOR GASEOUS MIXTURES. B. T. Wolfson and R. G. Dunn. USAF WADC TN 57-309 [AD 131024], May, 1959. 83 pp. 28 refs. Development of a simplified method to determine all detonation parameters for gaseous mixtures. The equations upon which the calculation procedure is based were derived directly from the conservation equa-

tions without approximations and involve only non-dimensional quantities. The agreement between values calculated by this method and experimental values is quite satisfactory.

COMBUSTION INTENSITY IN A HETEROGENEOUS STIRRED REACTOR. W. G. Courtney. (ARS Semi-Annual Meeting, San Diego, June 8-12, 1959.) ARS J., Apr., 1960, pp. 356, 357. 19 refs. Analysis of combustion intensity of liquid propellants, which involves deducing the steady-state concentration of partly burned drops that remain in the reactor when a polydispersed spray is fed into the reactor. The resulting equation is intractable, but an approximation to this equation shows that combustion intensity increases with increasing density of burned gas in the reactor, with increasing burning rate of a single droplet, and, particularly, with increasing number of smaller droplets in the feed spray. Quantitative prediction of combustion intensity is limited by severe uncertainty in the burning rates of droplets under turbulent reactor conditions.

Heat Transfer

CONCERNING THE PROBLEM OF THE INFLUENCE OF INTERNAL DEGREES OF FREEDOM OF PARTICLES ON THE TRANSPORT COEFFICIENTS OF A MULTICOMPONENT MIXTURE OF GASES. E. V. Samuilov. ARS J. Suppl., Apr., 1960, pp. 388-393. 11 refs. Translation. Analysis considering the effect of molecular collisions on the heat conduction coefficients and the shear and bulk viscosity coefficients. These molecule collisions include the following types: (a) elastic collisions occurring without a change in the vibrational quantum numbers v of the molecules, (b) elastic collisions accompanied with a change in the numbers v by unity - i.e., collisions that lead to an exchange of vibrational energy quanta between molecules, and (c) inelastic collisions accompanied by a change in the quantum numbers v of the molecules by unity. The probabilities of these molecular collisions are obtained from quantum-mechanics calculations of other investigators. The system of generalized kinetic equations is solved by the Enskog method.

VTOL & STOL

FORCE-TEST INVESTIGATION OF THE STABILITY AND CONTROL CHARACTERISTICS OF A 1/8-SCALE MODEL OF A TILT-WING VERTICAL-TAKE-OFF-AND-LANDING AIRPLANE. L. P. Tosti. US, NASA TN D-44, Mar., 1960. 127 pp. Presentation of measurements on short- and long-wing configurations of a model of the Hiller X-18 VTOL aircraft. The data are presented without analysis, and include both the longitudinal and the lateral stability and control characteristics in the normal-forward-flight, transition, and hovering ranges. Tests in the forward-flight and transition conditions were made at various wing incidences and power conditions. Tests in the hovering condition were made in the presence of the ground.

FLIGHT INVESTIGATION OF STABILITY AND CONTROL CHARACTERISTICS OF A 1/8-SCALE MODEL OF A TILT-WING VERTICAL-TAKE-OFF-AND-LANDING AIRPLANE. L. P. Tosti. US, NASA TN D-45, Mar., 1960. 25 pp. Presentation of test results obtained on a free-flight, remote-control model of the Hiller X-18. The investigation consisted of hovering flights in still air, vertical take-offs and landings, and slow constant-altitude transitions from hovering to forward flight. The stability and control of the model were found to be generally satisfactory with some exceptions. In hovering flight, the model had unstable pitching and rolling oscillations. The pitching oscillation could be controlled adequately even if the model were allowed to build up to an appreciable amplitude. If the rolling oscillation were allowed to build up to a modest amplitude, however, the oscillation could not always be controlled with the amount of control power proposed for the full scale airplane. In transition flight and at angles of incidence somewhere between 90° and 60°, the model experienced large nose-up pitching moments which severely limited the rearward center-of-gravity locations that could be used.

WIND-TUNNEL INVESTIGATION OF LONGITUDINAL AERODYNAMIC CHARACTERISTICS OF THREE PROPELLER-DRIVEN VTOL CONFIGURATIONS IN THE TRANSITION SPEED RANGE, INCLUDING EFFECTS OF GROUND PROXIMITY. Appendix - CHARACTERISTICS OF THE 17-FOOT TEST SECTION. R. E. Kuhn and W. C. Hayes, Jr. US, NASA TN D-55, Feb., 1960. 128 pp. Presentation of test results on the longitudinal aerodynamic characteristics of tilt-wing, deflected-slipstream, and combination tilt-wing/deflected-slipstream VTOL configurations in the transition speed range. The results are in general agreement with prior related investigations in that although the tilt-wing configuration requires the least power in hovering, the combination tilt-wing/deflected-slipstream configuration has relatively low power requirements throughout the transition speed range.

WATER-BASED AIRCRAFT

A STUDY OF SPRAY GENERATED BY SEAPLANE HULLS. Shizuo Kikuhara. J. Aero/Space Sci., June, 1960, pp. 415-428. Analysis in which the spray generated by seaplane hulls is explained by the same physical concept as in the slender-body theory of aerodynamics. The relation between two- and three-dimensional spray is made clear and demonstrated by experiments both in a towing tank and in a two-dimensional spray tank. An approximate theory of spray generation in two dimensions is presented for the case of straight wedges, which shows a fairly good agreement with the spray tank experiments. A groove-type spray suppressor was designed and tested in a towing tank. The effect of the new spray suppressor increases the load-carrying capacity of a hull by about 40% to 50% as far as the height of the spray is concerned.

ceramic-refractory metal fiber composites, using thermal shock resistance as the most important criterion.

Influence of Surface on Ceramic Mechanical Properties. G. R. Pulliam. *USAF WADC TR 59-261*, Sept., 1959. 30 pp. 16 refs. Study of the effect of gaseous and liquid environments, electromagnetic irradiation, and nonstoichiometry on the deformation and fracture processes in ceramic materials. The surface condition of the material and its chemical environment are found to have a large effect on these processes.

The System Titanium-Zirconium-Oxygen. Michael Hoch, R. L. Dean, C. K. Hwu, and S. M. Wolosin. *USAF WADC TR 59-539*, July, 1959. 74 pp. 37 refs.

Corrosion & Protective Coatings

A Method of Depositing Metallic Films on Non-Metallic Surfaces II—Electrical Resistance and Fine Structure of Copper Deposits and Polyester-Iron Substrates. N. C. W. Judd. *Gt. Brit., RAE TN Chem. 1357*, Nov., 1959. 15 pp.

The Influence of Some Process Variables on the Adhesion of Aluminium Spray Coatings. R. S. Smith, N. Stephenson, and T. A. Taylor. *Gt. Brit., NGTE Memo. M.331*, Nov., 1959. 24 pp.

An Adhesion Test for Aluminium Spray-Coatings and Other Metallised Surfaces. R. S. Smith and N. Stephenson. *Gt. Brit., NGTE Memo. M.329*, Nov., 1959. 13 pp.

Electrodeposition of Aluminum on Magnesium. E. W. Cooke and S. Kritzer. *USAF WADC TR 59-465*, Nov., 1959. 25 pp.

A Study of the Corrosive Effects of the Combustion Products of Boron Containing Fuels on Selected High Temperature Materials. Appendix I—**Static Test Photomicrographs.** Appendix II—**Heat Treatment, Furnace Test, and Dynamic Test Photomicrographs.** F. J. Loprest and S. J. Tunkel. *USAF WADC TR 57-542*, Sept., 1959. 291 pp. 22 refs. Presentation of a method for treating, in a quantitative manner, the corrosion data obtained. A rating of all the alloys tested is given, which includes a study of the critical temperature, the rate of corrosion below the critical temperature and its relation to the elemental composition of the alloy, the effects of the velocity of combustion products on the corrosion process, and the mechanisms of the process.

An Investigation of the Role of Gaseous Diffusion in the Oxidation of a Metal Forming a Volatile Oxide. J. L. Modisette and D. R. Schryer. *U.S., NASA TN D-222*, Mar., 1960. 25 pp. Analysis yielding a rate equation which expresses the oxidation rate as a function of temperature, gas properties, flow conditions, and the activation energy at temperatures at which the oxide is gaseous. An experiment performed with molybdenum is reported.

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The Effect of Properties of Materials for 1000°F Motors on Design Voltage for Optimum Specific Output. E. A. Linke. *SAE Natl. Aero. Meeting, Los Angeles, Oct. 5–9, 1959, Preprint 112T.* 9 pp.

Metals & Alloys

Short Time, Elevated Temperature, Stress-Strain Behavior of Tensile, Compressive, and Column Members. E. C. Bernett. *USAF WADC TR 59-484*, Dec., 1959. 131 pp. 12 refs. Presentation of test results for the following sheet materials: 2024-T81 aluminum, 17-7PH stainless steel, annealed N-155 (Multimet) alloy, and annealed 6Al-4V titanium alloy. Changes in testing speed produced a major difference in the tensile and compressive strengths, particularly at the elevated temperatures. It is also demonstrated that time-dependent deformation rates at high stresses and high temperatures are very rapid.

Příspěvek k Otázce Hodnocení Struktury Materiálu. Vratislav Horálek. *Aplikace Matematiky*, No. 3, 1958, pp. 376–383. In Czechoslovak, with summaries in English and Russian. Study covering the structure of materials and including a discussion of the relationship between the average number λ per unit volume of intersections of particles with a plane cross section on one hand, and the average number κ per unit volume of particles on the other.

Methods of Purification of Metals and Intermetallic Compounds. Sherman Susman. *USAF WADC TR 59-303*, Nov., 1959. 77 pp. 39 refs.

Research on Strain-Ageing, Hardening and Softening of Metals by Fatigue. I—The Fatigue of Aluminium-Magnesium Alloys. G. W. J. Waldron. *U. Birmingham Dept. Ind. Metallurgy Tech. Summary Rep. (AFOSR TN 59-774) [AD 219717]*, Sept., 1957–Feb., 1959. 74 pp. 56 refs. Investigation of the true fatigue limits and of the effect of temperature on fatigue life in aluminum-magnesium alloys.

Research on Strain-Aging, Hardening and Softening of Metals by Fatigue. II—Fatigue of Zinc Single Crystals. J. M. Summerton. *U. Birmingham Dept. Ind. Metallurgy Tech. Summary Rep. (AFOSR TN 59-774) [AD 219717]*, Sept., 1957–Feb., 1959. 48 pp. 22 refs. Presentation of a technique for growing large seeded zinc crystals of any desired orientation, a method of acid-machining gage lengths in these crystals, and a method for measuring hysteresis loops during fatigue.

Crack Propagation in Sheet Material—Some Conclusions Deduced from a Combination of Theory and Experiment. Appendix—**Effect of Local Increase of Radial Pressure on Local Hoop Tension.** D. Williams. *Gt. Brit., RAE TN Struc. 272*, Oct., 1959. 29 pp. Presentation of a method for determining crack propagation properties of sheet material. Simple formulas are established for correlating the results for small flat sheet specimens under tension or cylindrical specimens under internal pressure with those for larger but similar specimens.

A New Characteristic of the Fatigue Failure of Metals. V. S. Ivanova. *Sov. Phys. - Dokl.*, Feb., 1960, pp. 875–878. 16 refs. Translation. Discussion of the fatigue constant of the metal as a characteristic of fatigue failure induced by symmetrically cyclic stresses beyond the fatigue limit. The fatigue constant is defined as the difference between the stress which causes fatigue failure after a given number of cycles and the stress at which, after the same number of cycles, submicroscopic cracks begin to form.

Fatigue Tests on Notched Extruded Aluminium Alloy (DTD 364B) Having a Theoretical Stress Concentration Factor of 3.65. W. A. P. Fisher. *Gt. Brit., ARC CP 460* (June, 1959) 1960. 12 pp. BIS, New York, $0.36.

Effect of Mean Stress on Fatigue Properties of Aluminium Alloy Butt-Welded Joints. K. W. Gunn and R. McLester. *(B. W. R. A. Symposium on Fatigue of Welded Structures, Cambridge, Mar. 29–Apr. 1, 1960.) Brit. Welding J.*, Mar., 1960, pp. 201–208. Investigation of axial load fatigue on butt welded joints in order to provide comprehensive information on the fatigue of butt welds on which design data might be based.

Analysis of the Fatigue Rupture of Nimonic 90. C. S. Landau. *Gt. Brit., NGTE Memo. M. 333*, Oct., 1959. 7 pp. Application of the Graham and Walles method of analysis to define the shape of the *S-N* curve and its variation with temperature.

Increasing the Fatigue Strength of Butt-Welded Joints. Werner Gilde. *(B. W. R. A. Symposium on Fatigue of Welded Structures, Cambridge, Mar. 29–Apr. 1, 1960.) Brit. Welding J.*, Mar., 1960, pp. 208–211. Presentation of a method for increasing the dynamic strength of butt welds by covering the weld bead with a plastic surface coating.

Metallurgical Aspects of Future Research on Fatigue of Welded Structures. W. D. Biggs. *Brit. Welding J.*, Mar., 1960, pp. 212–216. Discussion of the mechanism of work hardening in relation to fatigue behavior, showing the need for experimental data on the effects of grain size and dispersions.

The Creep Strength of Some High Temperature Alloys at 1,050°–1,200°C. H. C. Child, A. B. Collier, and C. F. West. *Metallurgia*, Feb., 1960, pp. 51–54. Investigation of the creep strengths of typical wrought and cast austenitic alloys using a method whereby the specimen is bent as a cantilever, since there is considerable difficulty in extensometry for tensile testing at these high temperatures. In certain instances, the properties of wrought and cast materials are compared.

Continued Study of Advanced-Temperature Nickel-Base Alloys to Investigate Vanadium Additives. J. C. Freche, T. J. Riley, and W. J. Waters. *U.S., NASA TN D-260*, Feb., 1960. 34 pp. Investigation conducted to extend the useful temperature range of previously developed advanced-temperature nickel-base alloys. As-cast alloys with improved rupture and impact properties resulting from additions of vanadium and carbon, as well as tungsten, vanadium, and carbon, were evolved.

Technologie Výroby Spékaných Dílců. František Stojaspal. *Zpravodaj VZLÚ*, July-Aug., 1958, pp. 53–57. In Czechoslovak. Presentation of a method for manufacturing components by sintering, based on powder metallurgy. Powder production, powder molding and sintering, and the advantages of products manufactured by sintering are discussed.

Korelacja Pomiędzy Granicą Zmęczenia a Wskaźnikami Wytrzymałości na Rozciąganie, Skręcanie i Podwójne Ścinanie w Normalnych i Podwyższonych Temperaturach. Alfred Buch. *Inst. Lot. Prace*, No. 9, 1959, pp. 14–32. 30 refs. In Polish, with summaries in English, French, German, and Russian. Presentation of results on the correlation between the fatigue limit and the tensile, torsional, and shear strength characteristics of steel at normal and elevated temperatures.

Tension, Compression, and Fatigue Properties of Several SAE 52100 and Tool Steels Used for Ball Bearings. Appendix—**X-Ray Diffraction Studies of Several 52100 and Tool Steels.** G. Sachs, R. Sell, and V. Weiss. *U.S., NASA TN D-239*, Feb., 1960. 48 pp. 23 refs.

Effect of Hardness and Other Mechanical Properties on Rolling-Contact Fatigue Life of Four High-Temperature Bearing Steels. Appendix—**Stress-Cycle Relation.** T. L. Carter,

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E. V. Zaretsky, and W. J. Anderson. *U.S., NASA TN D-270*, Mar., 1960. 51 pp. 15 refs.

A Study of 17-7 PH Stainless Steel. N. L. Carwile and S. J. Rosenberg. *USAF WADC TR 58-653 [AD 216533]*, June, 1959. 36 pp. Presentation of mechanical properties and microstructures of 17-7 PH stainless steel as affected by heat-treatment.

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A Study of the Relationship Between Notched and Unnotched Specimens of 2024 Aluminum Alloy in the Low-Cycle Fatigue Regime. Richard D'Amato and Robert De Boer. *USAF WADC TN 59-2*, May, 1959. 70 pp.

The Effect of High Temperature Recovery on the Creep of Polycrystalline Aluminum in the Dislocation Climb Region of Temperatures. W. D. Ludemann, L. A. Shepard, and J. E. Dorn. *USAF WADC TR 59-131*, Dec., 1959. 28 pp. 32 refs.

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Development of Molybdenum-Base Alloys. I—High Strengths and High Recrystallization Temperatures in Wrought Molybdenum-Base Alloy Bar Stock. II—Molybdenum-Base Alloy Sheet Materials. M. Semchyshen, G. D. McArdle, and R. Q. Barr. *USAF WADC TR 59-280*, Oct., 1959. 126 pp. Study showing that annealing temperatures sufficient to recrystallize the core of the alloy sheets were inadequate to recrystallize the extreme surface layers. This "case effect" is attributed to contamination of the surface during rolling and annealing. Bendability of the sheet alloys was substantially increased by milling off these outer layers.

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A Large-Range Pneumatic Extensometer. N. L. Svensson. *IME Proc.*, No. 7, 1959, pp. 233–238; Communications, pp. 239, 240. Discussion of the design and development of a pneumatic extensometer suitable for the measurement of axial strains of the order 10^{-4} over a range of ±20 per cent, using a 1-in. gage length. The method of calibration and the method for analyzing the results are described.

The Use of Ultrasonic Methods to Determine Fatigue Effects in Metals. Rohn Truell, Bruce Chick, Amos Picker, and George Anderson. *USAF WADC TR 59-389*, Nov., 1959. 18 pp. Discussion of (a) the observed changes in ultrasonic attenuation and velocity in commercially pure 1,100 aluminum when subjected to slow continued stress cycling and (b) the delayed recovery phenomenon that appears when the cycling is interrupted.

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A—Angewandte Mathematik. (*GAMM Wissenschaftliche Jahrestagung, Hannover, May 19–23, 1959.*) *ZAMM*, Sept.-Oct., 1959, pp. 340–398. 83 refs. In German and English. *Partial Contents:* Der Raum der stetigen Funktionen in der Potentialtheorie, Gottfried Anger. Automatisches Programmieren bei Kleinrechenautomaten, K.-H. Bachmann. Exakte Lösungen einer Klasse von nichtlinearen erzwungenen Schwingungen, A. Blaser. Zur Fehlerabschätzung beim Iterationsverfahren linearer Randwertprobleme, Werner Bollermann. Neuere Lösungsmethode von linearen Differentialgleichungssystemen höherer Ordnung, K. Csébfalvi. Über die konforme Abbildung mehrfach zusammenhängender Gebiete, Dieter Gaier. Ambigeneous Stochastic Processes, A. Ramakrishnan. Symposium of papers covering the role of continuous functions in the potential theory; automatic programing of small computers; exact solutions of a class of nonlinear forced vibrations; error estimates in iteration methods for linear boundary problems; methods of solution for higher order, linear differential equations; conformal mapping of multiply connected regions; and ambigeneous stochastic processes.

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Probability, Statistics

The Probability Integrals of the Range and of the Studentized Range. II—Probability Integral and Percentage Points of the Studentized Range; Critical Values for Duncan's New Multiple Range Test. H. L. Harter, D. S. Clemm, and E. H. Guthrie. *USAF WADC TR 58-484, vol. II*, Oct., 1959. 293 pp. 15 refs.

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B—Allgemeine Mechanik. (*GAMM Wissenschaftliche Jahrestagung, Hannover, May 9–23, 1959.*) *ZAMM*, Sept.-Oct., 1959, pp. 398–411. In German. *Partial Contents:* Zur Frage der Lagrangeschen Lösungen beim *n*-Körperproblem, H. Fieber. Nichtlineare Probleme der Regelungstheorie, K. Magnus. Über die totale Stabilität erzwungener Bewegungen mit kombinierter Dämpfung, Rolf Reissig. Symposium of papers covering Lagrange solutions for the *n*-body problem; nonlinear problems in the control theory; total stability of forced motions with combined damping; and elementary systems in general systems' mechanics.

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Zur Dynamik der Linearsysteme. Václav Doležal. *Acta Technica*, No. 1, 1960, pp. 19–33. In German. Study of problems encountered in determining the behavior of linear physical systems. The system of integral differential equations defining the linear system is derived, and previously obtained results are evaluated.

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Note on Vertical Variations in Radar Reflectivity. C. W. C. Rogers. *MIT Dept. Meteorology WRR TN 1 (AFCRC TN 59-427)*, June, 1959. 14 pp. Presentation of the results of a survey involving the frequency of occurrence of detectable increases or decreases in radar reflectivity with height in the lower levels of the atmosphere. The relationship between variations in reflectivity with height and the vertical velocity profiles is discussed.

The Relation Between Cloudiness Over the Greenland Icecap and Synoptic Weather Types. C. A. Carpenter. *AMS Bul.*, Feb., 1960, pp. 68–78. Presentation of data on the cloudiness over the Greenland icecap route from Sondrestrom Air Base to Angmagssalik. Four types of synoptic systems are chosen and the cloudiness is summarized by types, both annually and for the summer season.

Services Aiding the Study and Recording of Meteorological Phenomena in Correlation with Radar Reflectivity Patterns of Precipitation as Observed at or Adjacent to the Blue Hill Meteorological Observatory, Milton, Mass. G. K. Thompson. *Harvard U. BHMO Final Rep. 5 (AFCRC TR 59-400)*, Oct. 31, 1959. 9 pp.

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The Aperiodic Diurnal Range of Temperature Over the North Atlantic Ocean. S. L. Rosenthal. *J. Meteorology*, Feb., 1960, pp. 78–83.

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Modification of Warm Maritime Airstreams Over Europe in Winter. I. J. W. Pothecary. *Meteorological Mag.*, Jan., 1960, pp. 1–7. Study of 125 occasions when stable, warm maritime air moved over cold ground in winter. It is found that dynamical processes are important, even though the cases were selected as far as possible to minimize these effects.

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A Climatological Analysis of Two Years of Routine Transosonde Flights from Japan. J. K. Angell. *Mo. Weather Rev.*, Dec., 1959, pp. 427–439. 11 refs. Navy-supported discussion of the trajectories and trajectory dispersion, the magnitudes and periodicities of the velocity and ageostrophic velocity components derived from the trajectories, and the separation between pairs of transosondes as a function of time after their release.

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Missile, Rocket, & Space Technology

Special Issue: First Annual Missile and Space Almanac. *Air Force Space Dig*, Apr., 1960, pp. 49–181. 232 refs. Discussion covering a brief description of space vehicles now in use or projected, design features of military missiles, tabulation of satellites and space probes, and data on the space system, as well as a missile and space glossary and bibliography.

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The Scientific Exploration of Space. G. D. Watson. *Can. Aero. J.*, Mar., 1960, pp. 81–89. 24 refs. Discussion of the use of space probes to obtain information about the solar system and interplanetary space. Mechanics of common orbits, typical space probes, and the question of motivation for space exploration are studied.

Manned Space Flight—Present and Future Steps. R. R. Gilruth and H. K. Strass. (*Manned Space Stations Symposium, Los Angeles, Apr. 20–22, 1960, Proc.*) *Aero/Space Engrg.*, May, 1960, pp. 16, 17, 88, 90. 10 refs. Abridged. Survey of the present status and future phases of manned space flight, discussed in the light of Project Mercury experience.

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Anisotropy of Escape Velocity from the Moon, the Lunar Atmosphere and the Origin of Craters. Louis Gold. *J. Astron. Sci.*, Spring, 1960, pp. 23, 24. Presentation of a simple estimate of the degree of anisotropy to be expected in the lunar escape velocity owing to the earth's gravitational field, which provides a basis for assessing the role of directed streaming of the moon's atmosphere (the lunar wind) as it might have contributed to the genesis of craters.

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Minuteman Weapon System. F. H. King. *Ordnance*, Mar.-Apr., 1960, pp. 808–810. Discussion of design objectives and characteristics of the three-stage solid-propellant missile.

The Rocket-Propelled Commercial Airliner. W. R. Domberger. *U. Minn. Inst. Tech. Dept. Aero. Eng. RAL Res. Rep. 135*, Nov., 1956. 24 pp. Discussion of the possibilities of a rocket-propelled airliner. The required design and performance characteristics, and the problems of launching and acceleration are studied. A description of a flight, from the passenger's point of view, is included.

Current Trends in Large Booster Developments. E. W. Hall and F. C. Schwenk. (*Manned Space Stations Symposium, Los Angeles, Apr. 20–22, 1960.*) *Aero/Space Engrg.*, May, 1960, pp. 20, 21. Abridged. Discussion of the booster applications being planned for the three major chemical rocket engines under development. The three engines are the Centaur 15K and the 200K using hydrogen-oxygen propellants, and the 1.5 million pound thrust F-1 engine using oxygen and RP-1. The use of the first two engines in Centaur and Saturn configurations is described. Estimates of payload capability are given for the Centaur, two versions (C-1 and C-2) of the Saturn, and the Nova vehicle.

Fantastic Vehicles Will be Realities. J. F. Judge. *Missiles & Rockets*, Mar. 28, 1960, pp. 17, 18, 22, 24. Discussion outlining the trend toward low-cost, high-performance, manned spacecraft. The effect of structural improvements on the gross weight-to-payload ratio of vehicles, the trend in propulsion systems, future nuclear-propelled ships, and economical considerations are examined.

Manned Rocket Flight Requires a Trade-Off Between Performance and Complexity. W. W. Hohenner. *Westinghouse Engr.*, Mar., 1960, pp. 54–58. Comparison of present rocket capabilities with the requirements for manned rocket flight to the moon. Reliability is found to be the most serious problem to be met in space travel.

Thermal Control of Space Vehicles—A Structural Approach. P. E. Glaser. (*Manned Space Stations Symposium, Los Angeles, Apr. 20–22, 1960, Proc.*) *Aero/Space Engrg.*, May, 1960, pp. 52, 53, 99, 100. 11 refs. Abridged. Study showing that the thermal protection system approach for the thermal control of space vehicles offers a feasible solution where long-term heating or cooling conditions and varying outside environments are encountered. Such factors as the principle of vacuum insulation, gas pressure, mechanical loads, thermal expansion, and surface coating are considered.

Thermal Protection of Space Vehicles. P. E. Glaser. *Astronautics*, Apr., 1960, pp. 40, 41, 105, 106. Presentation of insulation methods and approaches to insure structural integrity of a thermal protection system. Thermal protection methods for cryogenic fluids are also mentioned.

Platform Into Space. Rex Scambary. *Spaceflight*, Apr., 1960, pp. 162–166, 192. Description of the testing range at Woomera, including the equipment and weapons used.

Ballistics, Re-Entry

Minor Circle Flight at Large Angles of Inclination. W. H. T. Loh. *J. Aero/Space Sci.*, May, 1960, pp. 397–399. Presentation of equations to calculate flight velocity, flight altitude and altitude density, flight distance along flight path, flight range, flight deceleration and maximum deceleration, time rate and maximum time rate of average heat input per unit area, time rate and maximum time rate of local stagnation region heat input per unit area, and flight time.

Two Analytical Results of Fin-Stabilized Rocket Trajectory Under Quadratic Drag Law. K. S. Sung and C. Park. *J. Aero/Space Sci.*, May, 1960, p. 388.

On the Problems of Re-Entry Into the Earth's Atmosphere. A. C. Robinson and A. J. Besonis. (*USAF WADC TR 58-408*, Aug., 1958.) *J. Astron. Sci.*, Spring, 1960, pp. 7–21. 13 refs. Analysis of re-entry considering such problems as deceleration, heating, and accuracy of impact.

Guidance, Control, Stability

On Guidance and Control Requirements in Astronautics. R. E. Roberson. *Franklin Inst. J.*, Mar., 1960, pp. 196–220. Discussion of guidance and control requirements as to their need for specific mission reference. Mission characterizations are developed which give some broad indications of performance requirement trends. A "network" point of view toward trajectories is suggested which may have important implications in the establishment of classes of functional requirements.

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Manned Control of Orbital Rendezvous. E. Levin and J. Ward. (*Manned Space Stations Symposium, Los Angeles, Apr. 20–22, 1960, Proc.*) *Aero/Space Engrg.*, May, 1960, pp. 78, 79. Abridged. Description of a device simulating the essential features of the docking phase of the rendezvous operation. Human performance with this device is discussed.

Spacecraft

The Military Test Space Station. L. B. Smith. (*Manned Space Stations Symposium, Los Angeles, Apr. 20–22, 1960, Proc.*) *Aero/Space Engrg.*, May, 1960, pp. 18, 19. Abridged. Outline of the USAF position on the program encompassing the development, fabrication, and operation of a military test space station. The main requirements and presently envisioned tests are covered.

Some Factors Influencing the Selection of a Manned Space Station Concept. J. H. Doss and L. J. Montague. (*Manned Space Stations Symposium, Los Angeles, Apr. 20–22, 1960, Proc.*) *Aero/Space Engrg.*, May, 1960, pp. 28, 29, 94. Abridged. Discussion of factors considered in selecting the method for establishing a space station. Propulsion requirements, assembly and ground systems, reliability aspects, and economics are considered in evaluating the earth assembly and the orbit assembly approaches.

Space Station. *Flight*, Mar. 4, 1960, pp. 310–312, cutaway drawing. Presentation of the design and operation of a hypothetical, scientifically useful space vehicle which might be in operation "within the next few years." The scientific equipment of this vehicle is also discussed.

Solar Probes. S. W. Greenwood. *RAeS J.*, Mar., 1960, pp. 102, 103. Discussion of the speed requirements for solar probes. Orbits suitable for such vehicles and space probes already launched are also presented.

Dual Burning Propulsion Systems for Satellite Stages. B. P. Martin. *J. Astron. Sci.*, Spring, 1960, pp. 21–23. Analysis showing, by basic energy relationships, that a satellite vehicle system, whose last stage can be shut down and restarted, has a decided performance advantage over a system having only the conventional one-shot capability.

Observation Satellites: Problems and Prospects. I. A. H. Katz. *Astronautics*, Apr., 1960, pp. 26–29, 74, 76, 78, 80. 16 refs. Discussion of the photographic film systems, the resolution and the effect of the lens on the resolution values obtained in testing films, and the difference in scale and resolution. A short history of aerial photography is used as an introduction into the subject.

Satellite Astronomical Observatories. N. G. Roman. (*Manned Space Stations Symposium, Los Angeles, Apr. 20–22, 1960, Proc.*) *Aero/Space Engrg.*, May, 1960, pp. 86, 87. Abridged. Description of programs organized to provide for astronomical observations from satellites and rockets and discussion of the ultimate space astronomical observatory.

NASA Preparing Astronomical Satellite. F. G. McGuire. *Missiles & Rockets*, Mar. 14, 1960, pp. 26, 27, 30, 31. Discussion of the project aimed at developing a controllable astronomical satellite putting a payload of 3,500 lbs. into a 500-nautical-mile circular orbit and being oriented by stellar check points instead of earth.

Künstliche Erdsatelliten und Raumfahrt. III—Aufbau der Satelliten und Mondsonden. C. W. M. Tilenius. *VDI Zeitschrift*, Feb. 1, 1960, pp. 121–127. In German. Survey of the development in the field of artificial earth satellites. Data are presented on the design, instrumentation, and uses of various types.

Navigation

Application of Doppler Techniques to Space Navigation. F. B. Berger. (*Inst. Navigation 15th Annual Meeting, King's Point, N.Y., June 19, 1959.*) *Navigation*, Autumn, 1959, pp. 460–464. 13 refs. Discussion of the determination of one or more components of the velocity of a space vehicle by the use of various Doppler techniques. Earth-based, as well as vehicle-borne, systems are considered. The techniques are classified as active, cooperative, or passive; and their attributes, limitations, and applications are discussed.

Interplanetary Navigation. A. B. Mickelwait, E. H. Tompkins, Jr., and R. A. Park. *Sci. Am.*, Mar., 1960, pp. 64–73. Discussion of the problems encountered in interplanetary navigation. The problems of propulsion, prediction of the motion of a body through two or more simultaneously acting gravitational fields, achievement of an "escape" hyperbola path which leads to Venus or Mars, achievement of a minimum-energy orbit, selection of launching date, and information transmission are presented.

Intertial Navigation 1960. R. P. G. Collinson. *Flight*, Feb. 19, 1960, pp. 247–252. Discussion of the basic principles of inertial navigation, and description of some of the basic components. Possible civil applications are also discussed.

An Inertial Navigator's View of Old and New Gyroscopes. Frances Richey. (*Inst. Navigation*

Western Regional Meeting, March AFB, Cal., Jan. 23, 1959.) Navigation, Autumn, 1959, pp. 465–469. Presentation of the sources of error in a gyro considering gyro rotors suspended in a magnetic field, gyro rotors freely suspended by means of electrostatic supporting forces, and nuclear spin gyros.

Electronic Aids

Principles of Electronic Navigation Systems. P. C. Sandretto. *IRE Trans., ANE Ser.*, Dec., 1959, pp. 221–228. Description of various types of electronic navigation systems. The error rates and accuracies of the systems are discussed.

Design of a Quasi-Doppler UHF Direction Finder (Radio Direction Finder AN/GRD-11). R. C. Benoit, Jr., Francis Coughlin, Jr., and Stanley Kraszewski. *USAF RADC TR 59-106*. Nov., 1959. 25 pp.

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Nuclear Energy

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DESIGN ENGINEERS

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In 1949, Honeywell developed and flight tested the floated gyro for control systems. Since then, its Gyro Design Group has become the focal point for a multi-million dollar component development program, supporting the inertial navigation industry. This is, perhaps, the most advanced program of its kind. It has expanded rapidly and now has openings for additional top level engineers.

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Production

Metalworking

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Research, Research Facilities

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A High-Velocity Gun Emptying a Shock-Compressed Light Gas. Carlton Bioletti and B. E. Cunningham. *U.S., NASA TN D-307*, Feb., 1960. 19 pp. Discussion of the construction and performance of a light gas gun which can be used as a launcher for the investigation of various high-velocity phenomena.

Optimum Preventive Maintenance Policies. Richard Barlow and Larry Hunter. (*Oper. Res. Soc. Am. 15th Natl. Meeting, Wash., May 14, 15, 1959.*) *Oper. Res.*, Jan.-Feb., 1960, pp. 90–100. Study of two types of preventive maintenance policies. Optimum policies are defined and determined, in each case, as unique solutions of certain integral equations depending on the failure distribution. It is shown that both solutions are minimum-cost solutions. The two optimum policies are compared under certain restrictions.

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Dynamical Computations for an Ejection Seat Sled. K. N. Dodd. *Gt. Brit., RAE TN M.S. 59*, Oct., 1959. 8 pp. Presentation of a method for the calculation (on a high-speed computer) of the dynamics of a rocket-propelled vehicle to be used for ejection seat tests.

Wind Tunnels

The Equielastic Model Technique in Blown-Down Wind-Tunnel Tests. I—Determination of the Equielastic Model. Appendix—Frequencies and Modes of Vibration for a Solid Model. II—Example of Application. Luigi Broglio. *Roma U. Sch. Aero. Eng. Inst. Aero. Construc. Rep. SIAR 46 (AFOSR TN 59-409) [AD 214506]*, Dec., 1958. 45 pp. Presentation of a general procedure for determining (a) the pressure distribution on a solid model and (b) the tip rotation for a given wing structure. Numerical examples are given.

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Compressed Air Propels "Tri-Phibian" Helicopter. *Des. News*, Mar. 28, 1960, p. 4. Presentation of design characteristics of a cold-cycle pressure-jet helicopter ejecting compressed air through nozzle blade tips. Description includes

electrical or mechanical engineers

INTERESTING DIVERSIFIED HIGH-LEVEL POSITIONS

Honeywell introduced the first successful autopilot of World War II—the C-1. Since then we have produced more flight control systems than any other company. Today we are engaged in producing the automatic flight control system and the rate stabilization control system for Project Mercury, the flight reference system for the Titan, the solid state autopilot for the F-104, and the adaptive autopilot which controls flight through aerodynamic surfaces and reaction nozzles for the X-15.

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the rotor system, controls, power plant, and fuselage construction.

Wind-Tunnel Testing at Mach 9.0 *Spaceflight*, Apr., 1960, pp. 187–190. Presentation of the details of a new hypersonic wind tunnel now in operation at the Jet Propulsion Laboratory in Pasadena.

Development of the Spark-Heated, Hypervelocity, Blowdown Tunnel-Hotshot. R. W. Perry and W. N. Macdermott. *NATO AGARD Rep. 233*, June, 1958. 72 pp. 27 refs. Presentation of the history, description, performance, and typical test data for the first Hotshot-type wind tunnel. In addition, a brief account of advanced developments based on the electric-discharge method of heating gases is given.

Subsonický Aerodynamický Tunel Velkých Rozměrů. Vladimír Rameš. *Zpravodaj VZLÚ*, July-Aug., 1958, pp. 13–15. In Czechoslovak. Analysis of the principles involved in the development of closed-circuit wind tunnels, particularly those operating in the subsonic range.

Experimentální Metody v Transonické Oblasti. Miroslav Kryl. *Zpravodaj VZLÚ*, July-Aug., 1958, pp. 22–30. 12 refs. In Czechoslovak. Survey of experimental methods for aerodynamic research in the transonic range. The inadequacies of common subsonic and transonic wind tunnels and the reasons for transonic wind tunnels with perforated walls are discussed.

Streak Interferometry. F. D. Bennett, D. D. Shear, and H. S. Burden. *OSA J.*, Mar., 1960, pp. 212–216. 20 refs. Study of a modification of the Mach-Zehnder interferometer which permits streak interferometry of transient axisymmetric flows. Examples are shown of interferograms taken of flows produced by exploding fine metallic wires.

The Design and Use of Interferometers in Aerodynamics. L. H. Tanner. *Gt. Brit., ARC R&M 3131* (Sept., 1957) 1959. 66 pp. 21 refs. BIS, New York, $4.05. Survey of problems encountered in the design and use of interferometers on wind tunnels and shock tubes, and in the analysis and interpretation of interferograms. A mechanical analyser is described which performs the computation and plots the pressure distribution along any desired line.

"Morgandyne" Heat-Transfer Transducer and a Flame-Torch Calibration Technique for Hypervelocity Wind Tunnels. Appendix A—Calculation of Resistance Around a Copper Ring. Appendix B—Output Signal. Appendix C—Discussion of Electrical Properties of a Copper Plate with Thermal Gradients. Appendix D—Correction for Thermal Loss of the Calorimeter. Appendix E—Correction for the Finite Size of the Calorimeter Surface. C. C. Morgan and J. C. Andrews. *USAF AEDC TR 60-1*, Feb., 1960. 79 pp. Description of the transducers and related calibration equipment used to measure the transient heat transfer rates in arc-heated Hotshot hypervelocity wind tunnels.

A Technique for Firing Dynamically Scaled Missile Models in Wind Tunnels and for Measuring Rocket-Motor Sound and Pressure Fluctuations. W. J. Alford, Jr., and K. W. Goodson. *U.S., NASA TN D-224*, Mar., 1960. 43 pp. 16 refs. Review of the dynamic-similarity laws which are found to be applicable to both constant Mach number scaling and constant Froude number scaling. The design of rocket motors, providing reasonable scaled thrust time histories, is covered.

Rotating Wing Aircraft, Helicopters

Hélicoptères 1959. Etienne Ploix. (*4th Internatl. Aero. Congr. on Rotary Wings & Vertical Flight, Paris, June 15–19, 1959.*) *Tech. & Sci. Aéronautiques*, Aug., 1959, pp. 237–241. In French. Presentation of some results of a survey made during 1957–1958, covering the development and uses of various helicopter types. Such problems as noise, safety, and speed, as well as some legal and economic aspects, are briefly discussed.

The Hughes Model 269A Helicopter (Army HO-2). A. W. Bayer. *AHS Newsletter*, Mar., 1960, pp. 2–5. Presentation of the design and performance characteristics of a two-place helicopter.

Will the Autogyro Return? C. W. Thomas. *Aircraft* (Canada), Feb., 1960, pp. 22–26, 63. Discussion of the development of the autogyro, its operation, and uses. Differences between this type and a helicopter are noted, with emphasis being placed on the mechanical simplicity of the autogyro.

A Note Concerning Ship Motion and the Operation of Naval Fixed Wing Aircraft. Appendix—Increment in Vertical Velocity Due to Pitch and Heave. D. Johnson. *Gt. Brit., RAE TN Naval 40*, Nov., 1959. 23 pp. Discussion of the problems involved in operating naval aircraft from carriers under conditions of ship motion, in particular, pitching motion and heading variations.

L'Effet du Nombre de Mach sur les Rotors d'Hélicoptères. Yves Normand and Claudine Gaillot. *Tech. & Sci. Aéronautiques*, Aug., 1959, pp. 245–256. 11 refs. In French. Investigation of the effect of Mach number on helicopter rotors in hovering and forward flight. Diagrams are presented for calculating the required blade surface as well as the performance.

Etude et Essais des Rotors Semi-Rigides Multipales. W. L. Cresap. (*4th Internatl. Aero. Congr. on Rotary Wings & Vertical Flight, Paris, June 15–19, 1959.*) *Tech. & Sci. Aéronautiques*, Aug., 1959, pp. 221–230. In French. Evaluation of problems connected with the development of multibladed, semirigid helicopter rotors, including a survey of various rotor types and a discussion of preliminary studies, with the results obtained on the 47 and XH 40 models.

Rotary-Wing Agricultural Aircraft. *Agricultural Av.*, No. 1, 1960, pp. 12, 13. Presentation of technical data for 23 aircraft constructed especially for agricultural use, or adaptable to such use.

Un Etouffeur de Vibrations pour Hélicoptère Bipale. Th. Laufer. (*4th Internatl. Aero. Congr. on Rotary Wings & Vertical Flight, Paris, June 15–19, 1959.*) *Tech. & Sci. Aéronautiques*, Aug., 1959, pp. 231–235. In French. Study of the possible use of a dynamic damper for two-bladed helicopter rotors. Covered are such aspects as the vertical and horizontal oscillations, calculation of the horizontal damper, and some theoretical results.

Pozemní Rezonance Vrtulníků. Dimitrij Šejnost. *Zpravodaj VZLÚ*, Nov.-Dec., 1958, pp. 21–28. In Czechoslovak. Discussion of the physical meaning of the ground resonance phenomenon in helicopters. A mathematical development of dynamic differential equations is shown and formulas for plotting Coleman's diagram are given.

Częstość Kątowa Drgań Własnych Skrętnych Wirującej Łopaty Wirnika Nośnego Śmigłowca. Lechosław Kalinowski. *Tech. Lotnicza*, Nov.-Dec., 1959, pp. 155–161. In Polish. Calculation of the angular frequency of natural torsional vibrations of helicopter rotor blades.

Safety

Crash-Fire Protection System for a J57 Turbojet Engine Using Water as a Cooling and Inerting Agent. D. O. Black. *U.S., NASA TN D-274*, Feb., 1960. 35 pp.

The Effect of Some Halogenated Methanes on the Limits of Inflammability of Oxygen-Enriched Ethane-Air Flames. R. F. Simmons. *Gt. Brit., RPE TN 183*, Oct., 1959. 16 pp. Presentation of test results showing that while the agents tested are effective in extinguishing flames in air, their efficacy decreases as the oxygen content is increased, and at high oxygen contents they act merely as inert diluents until the flame temperature is reduced to a critical value. The significance of these results is also discussed in connection with the problem of fires involving hydrogen peroxide of high concentration.

Structures

Theory of Structural Design. Appendix I—Curvilinear Coordinates. Appendix II—Deformation and Equilibrium Conditions in Orthogonal Curvilinear Coordinates. W. S. Hemp. (*NATO AGARD 8th Structures & Materials Panel, Copenhagen, Oct. 20–25, 1958.*) *NATO AGARD Rep. 214*, Oct., 1958. 47 pp. Review of the results obtained by Cox from the theorems of Maxwell and Michell. Their current application is presented, the mathematical theory for the two-dimensional case is developed, and special solutions are derived.

Kilka Uwag na Temat Obliczania Wielokrotnie Statycznie Niewyznaczalnych Konstrukcji Segmentowych. Witold Gutkowski. *Arch. Budowy Maszyn*, No. 4, 1959, pp. 475–491. In Polish, with summaries in English and Russian. Comparison of exact and approximate solutions for multiple, statically indeterminate, bay constructions. The estimate of error for the approximate calculations varies from 5 to 20 per cent.

Bars & Rods

The Elastic-Plastic Bending of a Compressible Curved Bar. G. Eason. *Appl. Sci. Res., Sect. A*, No. 1, 1959, pp. 53–63. Presentation, for all the possible cases, of the displacements within a wide curved bar made of perfectly plastic, compressible material and subjected to pure bending moment.

Torsion of Prismatic Bars of Regular Polygonal Cross-Section. Wiesław Zapałowicz. *Arch. Mech. Stosowanej*, No. 5, 1959, pp. 559–593. Presentation of solutions in the form of infinite series for the torsion of bars having an arbitrary number of sides. The computations concerning the stresses and the warping show that the maximum stresses appear in the center of the sides of the polygon. During the torsion of a bar of the regular polygonal cross section, the principal diagonals and the centerlines of the sides are not displaced; the strata of the warped cross section constitute a system of curves symmetric with respect to these straight lines.

Beams & Columns

On Solutions for the Transient Response of Beams. R. W. Leonard. *U.S., NASA TR R-21*, 1959. 33 pp. 15 refs. Supt. of Doc., Wash., $0.40. Presentation of Williams-type modal solutions of the elementary and Timoshenko beam equations for the transient response of several uniform beams to a general applied load. Example computations are shown for a free-free beam subject to various concentrated loads at its center.

Ekonomiska Aluminiumprofiler—En Experimentell och Teoretisk Undersökning av I-Balkar Med Tunt Liv. Carl-Adolf Granholm. *Chalmers Tek. Högskolas Handlingar, No. 220*, 1959. 50 pp. 28 refs. In Swedish. Discussion of a standard series of aluminum I-sections. The investigation is conducted to verify practically the calculated risk of local buckling of webs and flanges under different conditions of loading.

Cylinders & Shells

Integral Equations of Equilibrium of Thin Elastic Cylindrical Shells. N. I. Remizova. (*Prikl. Mat. i Mekh.*, May-June, 1959, pp. 611–615.) *PMM—Appl. Math. & Mech.*, No. 3, 1959, pp. 872–879. Translation. Extension of Kil'chevski's method for solving the static problem in the theory of shells by reducing this problem to the treatment of a certain system of integral equations; application is made to the case of cylindrical shells.

On the Torsion of a Thin-Wall Cylinder Following a Plastic Extension. H. Payne and S. J. Czyzak. *J. Mech. & Phys. Solids*, Jan., 1960, pp. 39–44. USAF-supported analysis considering the problem of a cylinder of face-centered cubic crystalline material subjected to an incremental torsional strain following an existing tensile or compressive plastic strain, conducted to prove an extension of Taylor's model. Some agreement with experimental results has been obtained.

Recent Advances in the Buckling of Thin Shells. W. A. Nash. *Appl. Mech. Rev.*, Mar., 1960, pp. 161–164. 59 refs. Survey of the research done in the field of shell analysis covering single-layered isotropic shells, shells with internal pressure, stiffened shells, thermal effects, multilayered shells, and sandwich shells.

Thermal Stresses in a Long Circular Shell with Axial Temperature Variation. D. J. Johns. *J. Aero/Space Sci.*, May, 1960, pp. 393, 394. Analysis of the discontinuity stresses occurring at the junction of a shell with any other member having different thermal-expansion properties and/or temperature distributions. Thermal stresses are calculated for the bulkhead and the cylinder. In the latter case, the calculations are made for both the simply-supported condition and the clamped-edge conditions.

Elasticity & Plasticity

Variational Methods of Solution of Plasticity Problems. L. M. Kachanov. (*Prikl. Mat. i Mekh.*, May-June, 1959, pp. 616, 617.) *PMM—Appl. Math. & Mech.*, No. 3, 1959, pp. 880–883. Translation. Presentation of a method which enables a successful application of variational methods to the solution of problems in the theory of both plasticity and steady-state creep.

Über einige räumliche Probleme der Elastizitätstheorie. P. P. Teodorescu. *Aplikace Matematiky*, No. 4, 1959, pp. 225–238. 22 refs. In German. Discussion of some three-dimensional problems in the theory of elasticity. Based on the Beltrami equations and using Fourier series, a method is presented for the solution of the problem by means of three biharmonic functions or three or four harmonic functions. The results for the elastic half-space and the elastic layer are given.

General and Complete Solutions of the Equations of Elasticity. M. G. Slobodianskii. (*Prikl. Mat. i Mekh.*, May-June, 1959, pp. 468–482.) *PMM—Appl. Math. & Mech.*, No. 3, 1959, pp. 666–685. 22 refs. Translation. Discussion of the problem of expressing a set of displacement components satisfying the homogeneous equations of elasticity in terms of harmonic functions. The general solution of the equations of elasticity in terms of harmonic functions is defined and discussed.

New Concepts in Plasticity and Deformation Theory. V. D. Kliushnikov. (*Prikl. Mat. i Mekh.*, July-Aug., 1959, pp. 722–731.) *PMM—Appl. Math. & Mech.*, No. 4, 1959, pp. 1030–1042. Translation. Comparative analysis of some conclusions of three new theories of plasticity: Batdorf and Budiansky's slip theory, Sanders' theory based on linear loading functions, and a theory proposed by the author. Stress-strain relationships and Rabotnov's model which illustrates strain hardening properties of materials are discussed.

Hypothetical Theory of Anisotropy and the Bauschinger Effect Due to Plastic Strain History. Yoshimaru Yoshimura. *U. Tokyo Aero. Res. Inst. Rep. 349*, Nov., 1959. 27 pp. Presentation of a theory for predicting the state of anisotropy and the Bauschinger effect from the deformation history. Theoretical and experimental results are compared.

Theory of Plasticity for Small and Finite Deformations Based on Legitimate Concept of Strain. Yoshimaru Yoshimura. *U. Tokyo Aero. Res. Inst. Rep. 348*, Sept., 1959. 59 pp. Introduction of a new concept of strain suitable for the

description of plastic deformation, based on a new formulation of the theory of plasticity.

Influence of Intermediate Principal Stress on Plastic Flow. Fujio Nakanishi and Yasuo Sato. *JSME Bul.*, Feb., 1960, pp. 54–59. Study of the criterion of plastic flow in the range between tension and pure shear.

Direct Determination of Stresses from the Stress Equations of Motion in Elasticity. Józef Ignaczak. *Arch. Mech. Stosowanej*, No. 5, 1959, pp. 671–678. 12 refs. Presentation of equations of motion in the theory of elasticity derived in terms of time-dependent stresses. A complete solution is presented for the problem of stress distribution in the case of an infinite medium loaded by time-dependent arbitrary forces.

On the Elasto-Plastic Wave Propagation in Half-Space. Kh. A. Rakhmatulin. (*Prikl. Mat. i Mekh.*, May-June, 1959, pp. 419–424.) *PMM–Appl. Math. & Mech.*, No. 3, 1959, pp. 601–609. Translation. Presentation of an approximate method of solution for the problem of propagation of waves of weak discontinuity in a half-space, the boundary of which is subjected to the action of a normal pressure. It is found that for the cases of elasto-plastic waves a substantial role is played by longititudinal displacements—i.e., displacements in the direction of the given load on the boundary. The displacement in the plastic half-space near the boundary of the loading region is determined.

The Flow of Polycrystalline Metals Under Simple Shear. II. E. N. da C. Andrade and K. H. Jolliffe. *Royal Soc. (London) Proc., Ser. A*, Feb. 23, 1960, pp. 291–316. 22 refs. Investigation of the flow of lead of different purities under conditions of simple shear over a wide range of strain, at different stresses, and mostly at a temperature in the neighborhood of 27°C. Constants are derived which indicate that the flow in the quasi-viscous stage resembles that of a single crystal far more than that of a polycrystalline metal. The general implications of the experimental results are discussed.

Fatigue

Effect of a Stringer on the Stress Concentration Due to a Crack in a Thin Sheet. J. L. Sanders, Jr. *U.S., NASA TR R-13*, 1959. 10 pp. Supt. of Doc., Wash., $0.30. Determination of a coefficient for calculating the effect of a reinforcing stringer on the stress concentration factor at the tip of a crack in a thin sheet. The results are given for the case in which the stringer is intact and for the case in which the stringer is broken.

Equilibrium Cracks Formed During Brittle Fracture Rectilinear Cracks in Plane Plates. G. I. Barenblatt. (*Prikl. Mat. i Mekh.*, July-Aug., 1959, pp. 706–721.) *PMM—Appl. Math. & Mech.*, No. 4, 1959, pp. 1009–1029. 11 refs. Translation.

Plates

Bending of an Orthotropic Plate Clamped on the Boundary of a Conic Section. Y. Ohashi and T. Suzuki. *J. Aero/Space Sci.*, May, 1960, pp. 386, 387.

An Approximation to the Deflections and Strains in a Uniformly Loaded, Clamped, Rectangular Panel Subjected to Very Large Plastic Deformations. J. E. Greenspon. *J. Aero/Space Sci.*, May, 1960, pp. 392, 393.

Mezikruhová Deska v Pružně-Plastickém Stavu. Jan Dvořák. *Aplikace Matematiky*, No. 1, 1959, pp. 18–34. In Czechoslovak. Calculation of stresses and deformations in an annular plate, freely supported at one edge and subjected to a uniformly distributed loading along the other. The material of the plate is assumed to be isotropic, and the plasticity condition is given by the Huber-Mises-Hencky hypothesis.

Napětí a Deformace v Nekonečném Pasu, Zpusobené Hranovou Dislokací. František Kroupa. *Aplikace Matematiky*, No. 4, 1959, pp. 239–254. 13 refs. In Czechoslovak, with summaries in English and Russian. Determination of stress and deformation of an infinite strip caused by an edge dislocation. The solution is obtained by means of Fourier integrals. The importance of the results for the study of dislocations in a crystalline lattice and for the definition of the deformations of thin monocrystallic fibers by edge dislocation is pointed out.

The Buckling of a Circular Plate with a Concentric Circular Hot-Spot. K. I. McKenzie. *RAeS J.*, Mar., 1960, pp. 105, 106. Calculation of the critical temperature for a clamped plate supported in such a way that the radial stress in the cold part obeys the inverse square law.

Plates, Stiffened

Rozwiązywanie Konstrukcji Segmentowych Tarczowych za Pomocą Operatorów Macierzowych. Henryk Frączkiewicz. *Arch. Budowy Maszyn*, No. 4, pp. 453–473. In Polish, with summaries in English and Russian. Analysis of plane panel bay construction by means of matrix operators. As an example, the case of an infinitely long plane panel with four flanges and rigid ribs is solved.

Sandwich Construction

Materials and Processes. I—Sandwich Structure. H. R. Ashley. *The Aeroplane & Astronautics*, Mar. 4, 1960, pp. 283–287. Discussion of certain aspects in the development and application of honeycomb-stabilized sandwich structures to transonic and supersonic aircraft and missiles. The single-seat interceptor design is studied, and the choice of materials for high-temperature-resistant sandwich structures is discussed.

Honeycomb. I, II. P. J. B. Stevens and L. M. Polentz. *Materials in Des. Eng.*, Mar.; Apr., 1960, pp. 117–119, 122, 172; 123–126, 167, 168. Presentation of the basic formulas, design guides, and procedures required for the honeycomb sandwich construction. The various materials and the details of applications are given. The high strength-weight ratio, low thermal conductivity, and the vibration stability of the honeycomb structure are emphasized. Methods of joining honeycomb components and nonstructural uses are discussed.

Testing Methods

Spannungsoptische Untersuchungen an Schalen nach dem Einfrierverfahren. H. W. Hahnemann. *VDI Zeitschrift*, Feb. 1, 1960, pp. 119, 120. In German. Description of stress tests on shells by the photoelastic freezing method. An approximation formula for the calculation of maximum stress is obtained, and the stress distribution in a manifold under internal pressure is determined.

On the Photoelastic Examination of Vibrating Bodies and the Photoelastic Effect in Optically Active Media. A. F. B. Wood. *J. Mech. & Phys. Solids*, Jan., 1960, pp. 26–38. Discussion of the interpretation of photoelastic stress patterns with particular reference to quartz crystals. An expression is derived for the change in velocity of a light wave propagated along the optic axis due to stresses acting in the plane normal to this axis.

Different Applications of Photoelastic Layers in the Structural Field. G. Golubovic. (*BUFRA Paper*, Dec. 1, 1958.) *Gt. Brit., RAE Lib. Transl. 838*, Sept., 1959. 17 pp. Discussion of the theoretical bases of photoelasticity testing methods. Two testing machines are described, which operate on an actual specimen to which is attached a layer of photoelastic material. Examples of the use of the new method and machines are given.

Racionální Příprava Pevnostních Zkoušek Nosných Ploch. Bohuslav Hanák. *Zpravodaj VZLÚ*, Sept.-Oct., 1958, pp. 37–41. In Czechoslovak. Presentation of a simple method for the selection of common (fixed) loading points for all required loading cases.

Dynamometry s Odporovými Tensometry. Ivan Řezníček. *Zpravodaj VZLÚ*, Sept.-Oct., 1958, pp. 28–36. In Czechoslovak. Discussion of the principle, construction, and application of load measuring devices with resistance strain gages.

Přehled Metod Experimentální Pružnosti. Oldřich Kropáč. *Zpravodaj VZLÚ*, Sept.-Oct., 1958, pp. 15–27. 21 refs. In Czechoslovak. Survey of methods of experimental stress analysis classified into six typical groups. The characteristics and limitations of these groups are discussed and the methods are compared.

Thermal Stress

Some Three-Dimensional Problems of Thermoelasticity. Witold Nowacki. (*Prikl. Mat. i Mekh.*, May-June, 1959, pp. 456–467.) *PMM—Appl. Math. & Mech.*, No. 3, 1959, pp. 651–665. Translation. Investigation of thermal stresses caused by the action of nonstationary sources of heat, arbitrarily distributed in elastic and viscoelastic media. The construction of Green's functions for stresses caused by an instantaneous point source of heat is considered.

Steady-State Creep of Tin Near the Melting Point. W. A. Zama, D. D. Lang, and F. R. Brotzen. *J. Mech. & Phys. Solids*, Jan., 1960, pp. 45–51. 13 refs. Army-sponsored investigation of creep rates at temperatures between 180° and 230°C.

Effect of Camber on the Thermal Stresses and Deflections of Cantilevered Plates. R. J. H. Bollard and A. R. Zak. *4th Annual Conf. Solid Mech., Austin, Sept., 1959, Proc.* 16 pp. Reprint. Application of Reissner's variational principle to the analysis of thermal stresses and thermally induced transverse deflections of the middle surface of cambered cantilever plates of small aspect ratio. The results illustrate that the effect of even the smallest camber is appreciable in the thermal stress analysis of plates.

Wings

A Preliminary Analysis of the Penalties Associated with Piercing a Wing Torsion Box with a Grid of Holes. A. H. Hall. (*Canada, NAE LR 236*, Jan., 1959.) *Can. Aero. J.*, Mar., 1960, pp. 90–94. Analysis estimating the weight penalty incurred in restoring the wing stiffness to its original value for an aircraft modified by fans housed in the wing plane to provide VTOL capability.

Projektowanie Drewnianych Dźwigarów Skrzynkowych. D. P. Panzcowski. *Tech. Lotnicza*, Nov.-Dec., 1959, pp. 177–184, 187. 10 refs. In Polish. Presentation of methods for the design of wooden wing box spars, based on the Prager hypothesis.

Thermodynamics

Heat Transfer

On the Use of Normal Coordinates for the Solution of Lumped Parameter Transient Heat Transfer Problems. M. E. Gurtin. *J. Aero/Space Sci.*, May, 1960, pp. 357–360. Investigation showing how the matrix eigenvalue problem for heat transfer is set up and how the eigenvalues and eigenvectors are used to construct the transient solution. Two illustrative examples are given.

Fluxes and Non Dimensional Parameters in Radiant Gases. R. Goulard. *Purdue U. Sch. Aero. Eng. Rep. A-59-8*, Oct., 1959. 19 pp. 13 refs. Review of the fundamentals of the theory of radiation transfer in gases and of the mathematical aspects of the problem. Radiation fluxes in one-dimensional problems (slab configurations) are studied. The contribution of the wall to the radiative flux and the nondimensional radiation parameters in gas dynamics are discussed.

Heat Exchange in Plane Laminar Flow of a Viscous Fluid. V. I. Merkulov. (*Prikl. Mat. i Mekh.*, May-June, 1959, pp. 581, 582.) *PMM—Appl. Math. & Mech.*, No. 3, 1959, pp. 819–822. Translation. Study of the equation of steady heat exchange in a laminar flow of a viscous fluid. It is assumed that the heat conduction coefficient is constant and that the problem regarding the determination of the velocity field of flows considered has been solved.

The Effects of Resonant Acoustic Vibrations on Heat Transfer to Air in Horizontal Tubes. J. M. Spurlock, T. W. Jackson, K. R. Purdy, C. C. Oliver, and H. L. Johnson. *USAF WADC TN 59-330*, June, 1959. 46 pp. Presentation of experimental results indicating that a threshold sound pressure level exists below which little or no effect is produced. Above this value, significant increases of up to 75 per cent in the local average Nusselt numbers are produced.

Free Convection in Liquids (Partial Report). J. Plenier. (*Etabliss. Aéro. Toulouse GP Rep. (Etude 22P)*, Dec., 1958.) *Gt. Brit., RAE Lib. Transl. 833*, Sept., 1959. 25 pp. Description of experiments on free convection around a hot cylinder, and on the interior convection in a closed box. The results obtained are compared with those of other investigators.

VTOL & STOL

Preliminary Flight Experiments with the Princeton University Twenty-Foot Ground Effect Machine. W. G. Nixon and T. E. Sweeney. *IAS 28th Annual Meeting, New York, Jan. 25-27, 1960, Paper 60-54.* Members, $0.50; nonmembers, $1.00. 11 pp. Presentation of the operational experiences gained with a 20-ft.-diam. peripheral jet machine designed to examine stability, control, and performance. Studies of momentum drag indicate this factor to be smaller than anticipated. Other experiments with this machine include the measurement of control moments and control rates about each of the three axes, a measurement of augmentation ratio, and a comparison with theory.

Etude et Réalisation d'un Aéronef à Décollage et Atterrissage Vertical à Voilure Fixe et Propulsion par Rotors Hélices Inclinables. R. L. Lichten and J. R. Mertens. (*4th Internatl. Aero. Congr. on Rotary Wings & Vertical Flight, Paris, June 15-19, 1959.*) *Tech. & Sci. Aéronautiques*, Aug., 1959, pp. 199–212. In French. Historical survey of the development of a VTOL aircraft with fixed wings and tilt propellers. The Bell XV-3 configuration is described, including details of flight tests and wind-tunnel experiments, as well as future possibilities.

Water-Based Aircraft

A Brief Investigation of a Hydro-Ski Stabilized Hydrofoil System on a Model of a Twin-Engine Amphibian. S. M. Stubbs and E. L. Hoffman. *U.S., NASA TN D-220*, Feb., 1960. 21 pp. Presentation of results indicating that the tested supercavitating hydrofoil system mounted on an existing 1/8-size powered dynamic model of a twin-engine amphibian is capable of stable take-offs with available thrust and control. Some of the resistance characteristics during take-off and stability characteristics during take-off and landing are investigated.

A Method for Calculation of Hydrodynamic Lift for Submerged and Planing Rectangular Lifting Surfaces. K. L. Wadlin and K. W. Christopher. *U.S., NASA TR R-14*, 1959. 13 pp. 13 refs. Supt. of Doc., Wash., $0.30.

REVIEWS OF *Books*

. . . in the field of aeronautical engineering and space technology

AERODYNAMICS. FLUID MECHANICS

The Aerodynamics of Powered Flight. Robert L. Carroll. New York, John Wiley & Sons, Inc., 1960. 275 pp. $8.50.

The chief difference between this and other textbooks dealing with the aerodynamics of powered flight is its use of the rocket as an introduction to the subject. Considering the rocket as a system affording the greatest simplicity of analysis, the author has based the concept of lift on the analysis of rocket thrust. A transition is later made to the concept of a machine reacting upon the air to provide the lift and thrust necessary for achieving the final goal of powered flight in the atmosphere.

The book begins with a certain number of basic definitions that will be useful for purposes of self-study. Chapter 1 is an introduction to the mechanics of the problem. Then, with the mechanics of flow against a flat plate as explained in Chapter 2 modified to point the way to Bernoulli's law of fluid dynamics, Chapters 3, 4, and 5 develop the concept of lift and drag in incompressible flow. Compressibility effects in subsonic flow follow in Chapters 6 and 7. Chapter 8 introduces shock-wave formation and supersonic flight, and Chapters 9, 10, and 11 continue the development. Propeller theory is introduced in Chapter 12. Performance, stability, and control follow in the stated order. The final chapter is devoted to the discussion of aids in experimental testing.

Dr. Carroll is presently doing advanced space research with the American Machine and Foundry Co.; he was previously head of the Propulsion Performance Unit, Bell Aircraft Corp.

Hydromagnetic Channel Flows. Lawson P. Harris. Cambridge, Mass., The Technology Press of M.I.T.; New York, John Wiley & Sons, Inc., 1960. 90 pp. $2.75.

This monograph, which presents analyses for three flows of viscous, incompressible, electrically conducting fluids in high-aspect-ratio rectangular channels subjected to transverse magnetic fields, considers turbulent flows in the presence of a d.c. magnetic field and both laminar and turbulent conditions in induction-driven flows. The major purposes of the analyses are the development of an intuitive picture of the internal structure of a turbulent hydromagnetic flow and of calculation techniques for the estimation of the power division in these flows. The techniques employed in the study are analogous to the "semi-empirical" methods of hydrodynamics in their dependence on the combined use of the basic hydromagnetic equations, a dimensional analysis, and the results of the experiment.

Dr. Harris is an electrical engineer with the General Electric Research Laboratory, Schenectady, N.Y.

CHEMISTRY

Formation and Trapping of Free Radicals. Edited by Arnold M. Bass and H. P. Broida. New York, Academic Press, 1960. 522 pp. $16.

Contents: History of Radical Trapping, F. O. Rice. Radical Formation and Trapping from the Gas Phase, B. A. Thrush. Techniques of Electrical Discharge for Radical Production, Thomas M. Shaw. Radical Formation and Trapping in the Solid Phase, George C. Pimentel. Low Temperature Equipment and Techniques, F. A. Mauer. Optical Spectroscopy of Trapped Radicals, D. A. Ramsay. Electron Spin Resonance Studies of Trapped Radicals, C. K. Jen. Chemical and Physical Studies of Trapped Radicals, James W. Edwards. X-Ray Diffraction Studies and Their Crystal-Chemical Implications, H. S. Peiser. Free Radical Trapping—Theoretical Aspects, J. L. Jackson. Trapped Radicals in Astrophysics, Bertram Donn. Trapped Radicals in High Polymer Systems, H. Morawetz Trapped Radicals in Propulsion, Maurice W. Windsor. Trapped Radicals in Radiation Damage, R. S. Alger. Trapped Radicals in Biological Processes, C. H. Bamford and A. D. Jenkins. Chemical Utilization of Trapped Radicals, D. E. Carr. Author Index. Subject Index.

COMPUTERS

Digital Counters and Computers. Ed Bukstein. New York, Rinehart & Co., Inc., 1960. 248 pp. $7.00.

This book is written for the person who wishes to extend his knowledge into the area of computer techniques, and for the technician already working in this field who wishes to expand his understanding of the methodology of counting and computing. The author first discusses the basic mechanics of such components as flip-flop circuits, logic circuits, and switching circuits. He then proceeds to number theories and the counting systems by means of which the computing machinery performs its calculations. Other chapters deal with readout devices. One section discusses digital-analog and analog-digital conversion.

Ed Bukstein is an Instructor in Advanced Electronics, Northwestern Television and Electronics Institute.

DICTIONARIES

Aeronautical Dictionary. Frank Davis Adams. U.S. National Aeronautics and Space Administration. Washington, Supt. of Docs., 1959. 199 pp. $1.75.

This dictionary appears in response to numerous requests, culminated by a formal request from the Department of Defense, for a comprehensive, authoritative aeronautical dictionary, and is the direct successor to *NACA Report No. 474, Nomenclature for Aeronautics*, last revised in 1933. It has about 4,000 entries. In addition to aeronautical terms, it contains certain fundamental terms in related fields, such as navigation, meteorology, physics, and space technology, and also military and naval terms that are closely allied with aeronautics. Since the borderline between aeronautics and space technology is not always easy to define, and many terms are—or can be—applied in both areas, the definitions given are so worded as to take account of application in either field. Many terms in the fields of rockets and missiles are also included. There is a bibliography of publications from which citations were extracted for the dictionary.

Space Age Dictionary. Edited by Charles McLaughlin. Princeton, N.J., D. Van Nostrand Co., Inc., 1959. 128 pp. $5.95.

Most of the 1,200 terms are defined in a few lines, but some entries are encyclopedic in nature, running to several pages in length and accompanied by diagrams and formulas. There are brief descriptions of British, Soviet, and other non-American missiles and a table of satellites up to Pioneer IV. The author is President, McLaughlin Research Corp., New York.

ELECTRONICS

Modern Electronic Components. G. W. A. Dummer. New York, Philosophical Library, 1959. 472 pp. $15.

In this book the Head of Components Research, Development, and Testing, Royal Radar Establishment, presents a comprehensive survey of the characteristics of the commoner components. Selected bibliographies to many chapters direct the reader to more specialized information.

Contents: A Brief History of Component Development in Great Britain. Component Specifications and Publications. Colour Codes for Components. Conventional Symbols for Components. Fixed Resistors. Variable Resistors. Fixed Capacitors. Variable Capacitors. Wires, Covered Wires and Sleevings. Radio-Frequency Cables. Plugs and Sockets. Relays. Switches. Inductors and Magnetic Materials. Transformers, Transductors and Pulsactors. Batteries and Accumulators. Miscellaneous Components. Future Developments in Component Design. Components for Operation at High Temperatures. Short-Life Ratings of Components. The Performance of Components and Materials in the Tropics. The Performance of Components in Arctic and Antarctic Areas. Transistor Circuit Components (Miniature Components). Components for Use with Printed Wiring and Automatic Assembly Systems. The Effects of Casting Resins on Components. The Effects of Nuclear Radiation on Electronic Components. Components for Use at High Altitudes. The Effects of Vibration and Shock on Components. The Reliability of Components. Faults Which May Occur in Components. Component Testing Methods and Techniques. Packaging, Preservation and Identification of Components. Index.

Solid State Physics in Electronics and Telecommunications, Vol. 1, Semiconductors, Part 1. Proceedings of an International Conference Held in Brussels, June 2–7, 1958. Edited by M. Désirant and J. L. Michiels. New York, Academic Press, Inc., 1960. 638 pp. $18.

The conference drew some 800 active participants from 23 countries, and, in all, 250 papers were presented. Sixty-three of these papers are presented in Volume 1 under the following subject headings: preparations of semiconductors and applied problems, properties of semiconductors, effects of intense electric fields in semiconductors, solid-state theory, noise in semiconductors, and surface phenomena. In addition, Dr. W. Shockley contributes an introductory paper, "Crystals, Electronics, and Man's Conquest of Nature," which reviews the more important points raised by the several authors.

Industrial Electronics and Control. Royce Gerald Kloeffler. 2nd Ed. New York, John Wiley & Sons, Inc., 1960. 540 pp. $10.

The present edition differs from its predecessor by approaching the electronic theory of rectification, amplification, and oscillation through solid-state theory rather than by way of vacuum and gaseous tubes. The author, Professor of Electrical Engineering, Kansas State University, examines also such recent developments as solid-state thyratrons, cryotrons, and cold-cathode vacuum tubes. Two new chapters on semiconductors have been included. The material on servomechanisms has been completely rewritten, and information has been added on magnetic amplifiers, computers, and electronic measurement.

INSTRUMENTS

Altimetry and the Vertical Separation of Aircraft; A Reference Document of Findings and Conclusions Relating to Altimeters and the Vertical Separation of Aircraft. Montreal, Canada, International Air Transport Association, 1960. 24 pp.

MAINTENANCE

Aircraft and Missile Design and Maintenance Handbook. Charles A. Overbey. New York, The Macmillan Co., 1960. 369 pp. $9.75.

The main emphasis is on the practical aspects of aircraft and missile work. An attempt has been made to assist the reader in two ways—by providing, in a single source, data that heretofore have been scattered throughout the military and industrial literature and by presenting instructions for the proper use of tools and materials. Many of the data are presented in the form of easy-to-use reference tables. Special attention is given to information on glass-fiber reinforced plastics, titanium, cleaning processes, aircraft and missile tube fittings, and corrosion prevention. Power plants and electronics are treated only incidentally.

The author is an aeronautical design engineer and is associated with Convair-Astronautics.

MATERIALS

Magnesium and Its Alloys. C. Sheldon Roberts. New York, John Wiley & Sons, Inc., 1960. 230 pp. $9.00.

This is a reference book for persons seeking either isolated facts or a general picture of the science and technology of magnesium. It is not intended to serve as a shop manual or as a handbook for the structural designer. The extraction, refining, and casting of the metal, as well as its chemical and physical properties, are considered in detail. Dr. Roberts, who is Head, Materials Section, Fairchild Semiconductor Corp., Palo Alto, Calif., has included extensive lists of references, a bibliography, and a subject index.

MATHEMATICS

Analytic Functions. (Princeton Mathematical Series, No. 24.) Princeton, N.J., Princeton University Press, 1960. 197 pp. $5.00.

This book contains the principal addresses delivered at the Conference on Analytic Functions, September 2–14, 1957, Institute for Advanced Study, Princeton, N.J., which was called under contract with the Air Force Office of Scientific Research.

Contents: On Differentiable Mappings, R. Nevanlinna. Analysis in Non-Compact Complex Spaces, H. Behnke and H. Grauert. The Complex Analytic Structure of the Space of Closed Riemann Surfaces, L. V. Ahlfors. Some Remarks on Perturbation of Structure, D. C. Spencer, Quasiconformal Mappings and Teichmüller's Theorem, L. Bers. On Compact Analytic Surfaces, K. Kodaira. The Conformal Map-

ping of Riemann Surfaces, M. Heins. On Certain Coefficients of Univalent Functions, J. A. Jenkins. Appendix: Papers Presented in the Seminars (Titles and Authors).

MISSILES, ROCKETS.

First Symposium—Surface Effects on Spacecraft Materials, Held at Palo Alto, Calif., May 12 and 13, 1959. Sponsored by Air Research and Development Command, USAF, and Missiles and Space Division, Lockheed Aircraft Corp. Edited by Francis J. Clauss. New York, John Wiley & Sons, Inc. 1960. 404 pp. $11.50.

Contents: Welcoming Remarks, John P. Nash. Introductory Address, John W. Sessums. Effect of Surface Thermal-Radiation Characteristics on the Temperature-Control Problem in Satellites, Walter G. Camack and Donald K. Edwards. Temperature Control of the Explorers and Pioneers, T. O. Thostesen, A. R. Hibbs, and E. P. Buwalda. Coatings for Space Vehicles, Joseph C. Richmond. Spectral Reflectance Measurements, Robert V. Dunkle. Emissivity of Materials Near Room Temperature, Ralph McDonough. Vanguard Emittance Studies at NRL, Louis F. Drummeter, Jr., and E. Goldstein. Emissivity, Absorptivity, and High-Temperature Measurements at Armour Research Foundation, O. H. Olson and Sidney Katz. Some Methods Used at the National Bureau of Standards for Measuring Thermal Emittance at High Temperatures, Joseph C. Richmond. A Method for Measuring Total Hemispherical Emissivity of Metals, C. P. Butler and Edward C. Y. Inn. High-Temperature Emissivity Measurements at The Martin Company, Melvin Crompton. Apparatus for the Measurement of Spectral and Total Emittance of Opaque Solids, Clyde C. Shaw. Material Sublimation and Surface Effects in High Vacuum, G. F. Vanderschmidt and J. C. Simons, Jr. Vacuum Volatility of Organic Coatings, George F. Matacek. Effects of High Vacuum on Mechanical Properties, M. R. Achter. Surface Phenomena and Friction, T. Bruce Daniel. Panel Discussion: High-Vacuum Environmental-Test Chambers and Equipment, M. R. Achter, T. B. Daniel, R. L. Jepsen, G. F. Matacek, N. Milleron, E. Perkins, J. P. Reynolds, J. C. Simons, and G. F. Vanderschmidt. Measurements of Extreme Ultraviolet Solar Radiation and Associated Photoelectric Emissions from Solids, Hans E. Hinteregger. The Effects of Ultraviolet Radiation on Organic Film-Forming Polymers, J. E. Cowling, A. Alexander, F. Noonan, R. Kagarise, and S. Stokes. Interplanetary Dust Distribution and Erosion Effects, David B. Beard. Atomic and Molecular Sputtering, Robert P. Stein.

POWER PLANTS

The Internal-Combustion Engine in Theory and Practice; Vol. 1, Thermodynamics, Fluid Flow, Performance. Charles Fayette Taylor. Cambridge, Mass., The Technology Press of M.I.T.; New York, John Wiley & Sons, Inc., 1960. 574 pp. $16.

Volume 1 of this two-volume work is devoted to establishing a background for new design and development and for the proper evaluation of the performance of existing types of internal-combustion engines. Volume 2 will deal with fuels, combustion, carburetion, fuel injection, engine balance and vibration, and detail design.

The subject matter dealt with includes the relation of actual engine cycles to corresponding ideal fuel-air cycles, the air-capacity and fluid-flow characteristics of four-stroke and two-stroke engines, engine friction, and generalized performance curves of different types of compressors. An analysis is made of the influence of cylinder size on engine characteristics, and the final chapters present methods of performance analysis and prediction and typical generalized performance curves for various engine, compressor, and turbine combinations. Additionally, there are sections, entitled "Illustrative Examples," which show how material in the various chapters can be used to solve practical design and performance problems.

Following the last chapter are eight appendixes containing design information in the form of curves, charts, and tables. As far as possible, these data are presented in dimensionless form so that they can be applied independently of units of measure or cylinder size. Also, there is a selected bibliography of some 550 references which is arranged so as to apply to particular chapters in the book.

This volume is a product of the author's many years of research and industrial experience and incorporates the results of work done at the Sloan Laboratories of M.I.T. C. F. Taylor is Professor of Automotive Engineering, M.I.T.

PROPELLANTS

Rocket Propellant Handbook. Boris Kit and Douglas S. Evered. New York, The Macmillan Co., 1960. 354 pp. $12.50.

The handbook is divided into several parts, the first of which discusses basic topics in propulsion technology. The main body of the book (Parts 2 and 3) treats of inorganic and organic propellants, and the following order has been adopted for discussion of each propellant: (1) a brief introduction providing background material; (2) data on physical and chemical properties; (3) methods of production, availability, and economic feasibility; (4) problems of storage and handling; (5) toxicity; and (6) performance. A set of references and a bibliography are provided for each propellant. Since pressurizing gases are used in propellant feed systems, data on air, helium, and nitrogen are discussed, in Part 4. Definitions of physical properties appear in Appendix 1, and conversion factors, physical constants, and tables of thermodynamic data in Appendixes 2 and 3.

Boris Kit is Head of the Physics and Chemistry Program, Air Information Division, Library of Congress; Douglas Evered is Head of Market Requirements, Hughes Aircraft Co.

RESEARCH

Engineering College Research Review, 1959. Edited by Renato Contini and Paul T. Bryant. 9th Ed. Urbana, Ill., Engineering College Research Council, American Society for Engineering Education, 1959. 445 pp. $2.00.

The 1959 biennial volume surveys more than 10,000 projects under way in 118 schools that hold ECRC membership. The numbers of research personnel at each institution are listed, research income and expenditure are given, and research policies are summarized. Names of research officers are included, and there is an index of research projects by subjects.

SPACE TRAVEL

Moon Base; Technical and Psychological Aspects. T. C. Helvey. New York, John F. Rider Publisher, Inc., 1960. 72 pp. $1.95.

In this work the Director of Biophysics and Astrobiology Branch, Radiation, Inc., presents the main problem areas in the construction of a lunar base, including the crew shell, maintenance and crew equipment, and means of communication. In the section on human factors he discusses the physical, medical, dental, and psychological parameters that may determine the composition of the smallest operational crew.

STRUCTURES

Theory of Plates and Shells. S. Timoshenko and S. Woinowsky-Krieger. 2nd Ed. New York, McGraw-Hill Book Co., Inc., 1959. 580 pp. $15.

Since the appearance of the first edition in 1940, the application of the theory of plates and shells in practice has widened considerably, and some new methods have been introduced into the theory. This is reflected by many changes and additions. The principal additions are an article on deflection of plates due to transverse shear, an article on stress concentrations around a circular hole in a bent plate, a chapter on bending of plates resting on an elastic foundation, a chapter on bending of anisotropic plates, and a chapter reviewing certain special and approximate methods used in plate analysis. The authors have expanded the chapter on large deflections of plates and added several new cases of plates of variable thickness and some numerical tables facilitating plate analysis. In the part of the book dealing with the theory of shells, they have limited themselves to the addition of the stress-function method in the membrane theory of shells and to minor additions in the flexural theory of shells. There are copious footnotes and name and subject indexes.

Dr. Timoshenko is Professor Emeritus of Engineering Mechanics, Stanford University; Dr. Woinowsky-Krieger is Professor of Engineering Mechanics, Laval University.

Publications abstracted may be borrowed from the IAS Library. In making inquiry, please mention the month of Aero/Space Engineering in which the abstract appeared. This will facilitate servicing of requests.

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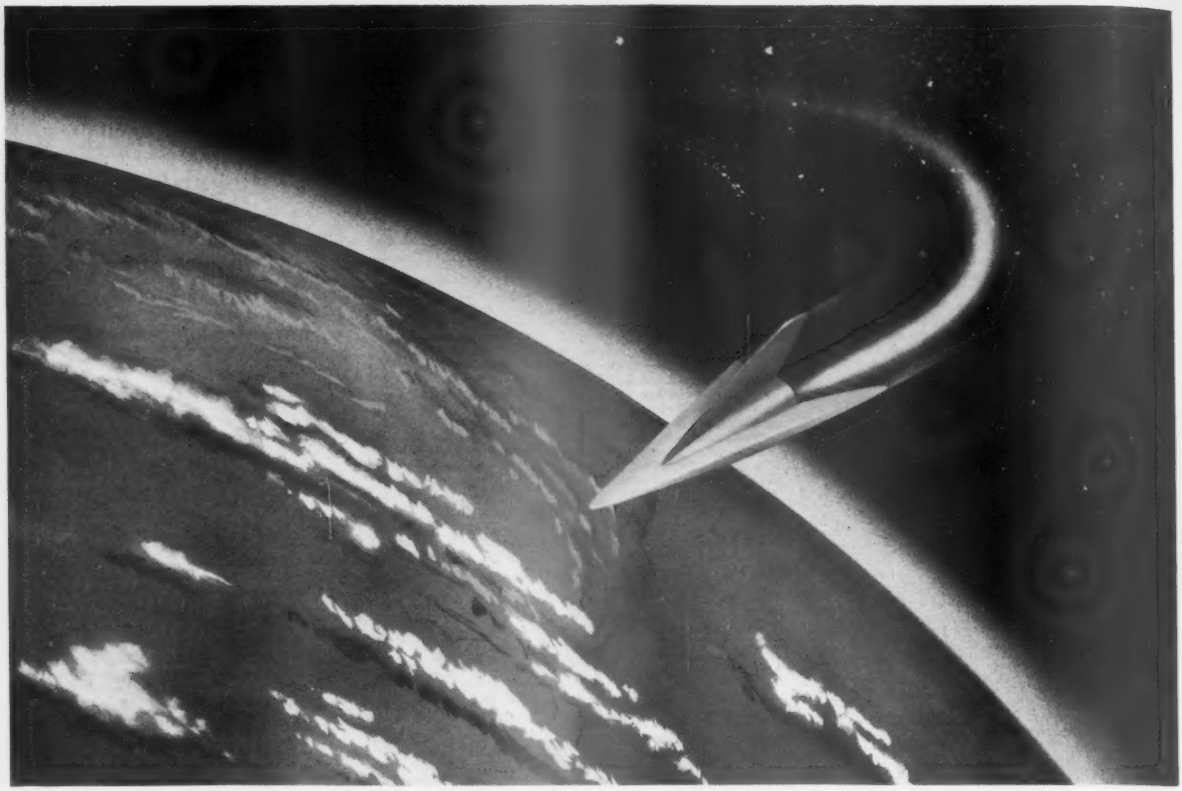

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Personnel Opportunities

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Wanted

Aerodynamicists—The Computation and Analysis Laboratory of the Naval Weapons Laboratory has openings in applied research for aerodynamicists with strong backgrounds in both theoretical and experimental missile aerodynamics, preferably throughout the subsonic to hypersonic speed ranges. A working knowledge of advanced mathematics is highly desirable. Appointees will work in an established and growing laboratory which is involved in determining the dynamic performance of missiles and space vehicles utilizing one of the world's fastest and most accurate digital computers, the Naval Ordnance Research Calculator (NORC). Positions with starting salaries up to $11,595, depending upon the qualifications of applicants, are available. Inquiries should be addressed to Industrial Relations Director, Naval Weapons Lab., Dahlgren, Va.

Teaching Positions—in fluids, heat transfer, aerodynamics, aerospace. Large and rapidly growing graduate program through D.Sc. Sponsored research encouraged. Salary and rank commensurate with educational background. Apply: C. T. Grace, Chairman, Mechanical Engineering Dept., University of New Mexico, Albuquerque, N.M.

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966. Systems/Project Engineer—age 35, B.S.E.E., Professional Engineer M.E. (California). Ten years' experience in machine design, systems and project engineering on large developmental jobs; 5 years in engineering supervision including proposals, estimating, design, fabrication, testing, and installation. Familiar with stress and deflection analysis, hydraulics, electromechanical systems, supersonic airflow, and heat transfer. Seeks responsible position with progressive small company on East Coast.

965. Aeronautical Engineer—B.Aero.E., age 24, completing 3 years of aircraft maintenance supervisory experience in July with USAF. Desires position in New York City starting in August in the thermodynamic equipment design field with a nonmilitary contracting firm. Planning part-time study at a local university for a Master of Mechanical Engineering degree.

963. Aeronautical Engineer—M.S.Ae.E. (Dynamics), age 31. Four years' engineering experience in airplane and helicopter aerodynamics, stability and control, and analog computations; 3½ years' aeronautical engineering teaching experience (undergraduate level). Former Naval Aviator. Desires career teaching position with opportunity for consulting or applied research work.

962. Aircraft Stress Analyst, Structural and Mechanical—B.Sc., age 27, MIAS. Seven years in aircraft industry. At present engaged on structure and mechanism design and analysis of new civil jet. Desires a position giving wider scope than at present with an aircraft or components manufacturer.

961. Aerospace Executive—Director, Division Manager, Chief Engineer, Engineering Manager, etc. Present position engineering manager, previous position manager of engineering division—medium-sized companies. Graduate M.E. and licensed professional engineer; member IAS, SAE, ASME, ARS with heavy proved R&D background and associated administration, cost, sales, and production engineering experience—all in aerospace hydraulics, mechanics, electromechanics, electronics, and pneumatics, principally in the fields of controls and power accessories. Also has proved inventive ability—many patents. Last 10 years in management, organization, and direction of groups in charge of analysis, design, development, and test of aerospace and related prototype and production equipment. Desires new connection with stable A-1 aerospace company.

960. Aeronautical Scientist—Former professor of mathematics; M.S. Broad experience in aeroballistics, flight mechanics, systems operational analysis, flutter dynamics, inertia characteristics. Ready for long-term (3–5 year) opportunity in closed-loop control systems research, working through basic theory to applications. Professional quality work, results guaranteed eventually.

959. Aeronautical Engineer—age 35; B.S. in A.E. One year teaching college undergraduates plus 9½ years of diversified industry experience in aircraft flight handbooks, product R&D, project aerodynamic performance, and advanced-design analysis, including successive levels of responsibility and supervision relating to a wide variety of military and commercial piloted aircraft and air-breathing missiles. Presently in advanced design aerodynamics and development of practical vertical-flight vehicles. Desires challenging career opportunity in applied R&D with a progressive V/STOL and/or GEM development contractor—military, commercial, or research types. Interesting work and growth potential are of paramount importance. Will consider only East Coast location. Résumé on request.

958. Experienced Engineer—age 32; M.S. in M.E. Currently head of applied analysis group, advanced design section of a major missile airframe company, desires position with medium-size growing company, not necessarily airframe. Offers 9 years' experience plus proved ability to produce results in exchange for challenging, responsible position with opportunity to share in company growth. Résumé upon request.

957. Aeronautical Engineer—Recent graduate desires active and diversified position in test engineering. Has experience in stress engineering and materials review board. Prefers location New York and vicinity or California. Résumé furnished on request.

956. Technical Writer/Editor—Journalism-based woman writer, in aircraft engineering since 1956. Background includes 10 years as industrial writer/editor. Works closely with engineering personnel to prepare reports, proposals, R&D manuals, special publications, promotion copy. Seeks position in Los Angeles area. Résumé and detailed work history on request.

955. Staff Engineer—Structures research and analysis. Strong background in R&D of advanced structural concepts for normal and high-temperature environmental conditions; 18 years' experience in research, design, analysis, and teaching. M.S. degree in Engineering. Age 44. Desires to locate on West Coast or in Southwest. Complete résumé upon request.

954. Aeronautical Engineer—Dr. Engrg. Sci. (aerodynamics and applied mathematics). Eight years' university research, 3½ years' industrial R&D in theoretical fluid dynamics and applied mathematics pertinent to aircraft and spacecraft, 2 years' part-time teaching (fluid dynamics). Publications. Desires teaching position with university that has ample research opportunities.

953. Aeronautical Engineer—B.S. degree, Aeronautical Engineering. Thirteen years' experience wind-tunnel testing in subsonic, transonic, and supersonic regimes at the California Institute of Technology. Age 38. Responsibilities: planning tests, accomplishing actual testing, analyzing data, and final data report preparations and reviewing. In addition 10 years 'experience in supervisory capacity as aerodynamic group leader responsible for technical work of a group of engineers and technical aides.

952. Field Service Engineer/Supervisor—Thirteen years with present employer. Good background; hydraulic, electromechanical, electronic controls, rotating machinery. Desires position with growth potential. Age 42, current salary $10,000 plus. Excellent high-level contacts in missile and airframe industry. Free to travel but prefers West Coast headquarters.

951. Senior Grade Engineer—earning five figure salary desires opportunity to expand into administrative, supervisory, or technical sales field. Age 30. B.S.M.E., 1952; M.B.A., management, 1960. Eight years of varied experience in structural design, testing, and production of military aircraft. Principally engaged in structural testing, environmental testing, and application of passive element analog computing techniques to design problems.

950. Aeronautical Engineer.—B.S.Ae.E. Has broad technical experience basically in aerodynamics, dynamics, power-plant installation design, flight-test engineering, and flight safety. Foregoing experience is backed up with supervisory, administrative, and project engineering activity related to design and test specification preparation, scheduling, budgeting, personnel administration, and customer contact. Desires location as chief engineer in small growing aircraft, missile, or space development organization.

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IAS Section News (Continued from page 60)

new sociological demands like space flight.

The most readily obtainable new source of power appears to be from the reserves of uranium-thorium compounds since power has already been extracted successfully on a nearly competitive basis with the fossil fuels. Lower cost of uranium-thorium fuels will be realized, according to Dr. Fisher, if plant construction costs can be reduced. Excluding distribution, it now costs 25 mils per kwh. to produce nuclear power, compared to 10½ mils for coal.

Dr. Fisher concluded that there is absolutely no danger of running out of power sources in the foreseeable future; despite a rapid population growth, he thought the uranium-thorium reserve was good for 1,500 years and the deuterium supply for about 30 million years. Solar radiation would also be equally dependable, thus allowing ample time to figure out how to capture this energy.

N. R. BERGRUN, *Secretary*

Seattle Section

High Temperatures in Missile Structures

Dr. Nicholas J. Hoff, Head of the Department of Aeronautical Engineering at Stanford University, addressed the March 28 meeting on the subject of **"High Temperatures in Missile Structures."**

By way of introduction, Dr. Hoff showed the high temperature available from aerodynamic heating at hypersonic speeds. Various methods of achieving these temperatures in the laboratory, including quartz lamps, gas-turbine exhaust, solar furnace, and electric induction were described. He pointed out that heat travels relatively slowly through metal and that this fact leads to large temperature gradients throughout a missile structure which produces stresses caused by unequal expansion of the various parts. He then demonstrated a method for computing the buckling stress of a plant loaded in compression and heated at both ends.

Considerable discussion was given to the problem of structural creep. The three phases of creep distortion were described as were its nonlinear characteristics under varying loads. It was pointed out that the computation of stresses in redundant structures was made very difficult if creep existed since this type of distortion did not follow Hooke's law.

Hoop stresses in a cylinder restrained at its ends and heated was the final structural problem described. Dr. Hoff concluded with discussion of the requirements for heat sinks and ablation devices for re-entry vehicles.

JOHN K. WIMPRESS, *Secretary*

Tullahoma Section

Arnold Engineering Development Center

The March 29 dinner meeting presented a Summary of Testing Activities in the facilities of the Arnold Engineering Development Center. The purpose was to provide attendees with an overall picture of the scope of the testing activities conducted in the three facilities. The briefing was conducted by chiefs of the facilities—R. W. Hensel, Propulsion Wind Tunnel Facility; J. Lukasiewicz, von Kármán Gas Dynamics Facility; and J. Ferrell, Engine Test Facility. Slides and motion picture film strips were used by the speakers as illustrations during the briefing.

WILLIAM L. CHEW, JR., *Secretary*